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IN MEMORIAM

W. L. Scofield

W. L. Scofield, former director of the California State Fisheries Laboratory, passed away September 27, 1966, in Long Beach. He retired from the California Department of Fish and Game on December 31, 1955, after almost 37 years of state service.

Mr. Scofield was graduated from Stanford University in 1911 with a degree in botany. In 1913 he received his master's degree from the Yale University School of Forestry.

A veteran of World War I, he worked for the United States Forest Service before beginning his career with the State in April 1919. He first worked on salmon investigations at Monterey. In 1920 he transferred to sardine studies.

Mr. Scofield was appointed director of the California State Fisheries Laboratory at Terminal Island in March, 1925. In January 1942, he was made public relations coordinator and liaison representative for the then Marine Fisheries Branch and other branches of the Department of Fish and Game.

He wrote several outstanding publications on various types of commercial fishing gear, and also compiled comprehensive historical accounts of California's fishing ports and on kelp harvesting in the State. The latter was compiled and published after his retirement.

Mr. Scofield's exceptional knowledge of the history of California's fishing industry and of early regulations aided materially in building a strong foundation for the Department's marine resources program.

To his family, his many friends throughout the Department extend their sincere sympathy.—*Phil M. Roedel.*

Calif. Fish and Game, 53 (1) : 5–22. 1967.

FIVE SPECIES OF SALMON, *ONCORHYNCHUS*, IN THE SACRAMENTO RIVER, CALIFORNIA[1]

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Marine Resources Branch
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King salmon *(O. tshawytscha)* are abundant in the Sacramento-San Joaquin river system of California, but other species of salmon are uncommon or rare. To determine the occurrence and abundance of the less common species, all such fish encountered during routine king salmon studies and hatchery operations were examined and recorded. From 1949 through 1958, a total of 130 chum, pink, sockeye, and silver salmon *(O. keta, O. gorbuscha, O. nerka, and O. kisutch)* was identified. All were from the Sacramento, its tributaries, or the Sacramento-San Joaquin Delta. No salmon other than kings were found in the southern tributaries of the Delta. These 130 fish do not include planted silver salmon, which began entering the rivers in 1956. After this planting was discontinued, silver salmon rapidly declined and have almost vanished from the Sacramento. Highly tentative estimates were made of the numbers of chum, pink, and sockeye salmon occurring in the Sacramento River system. It was concluded that these three species are present as very small spawning runs, but that silver salmon were so scarce that they should be regarded as strays.

INTRODUCTION

Five species of salmon, genus *Oncorhynchus*, are common to the Pacific Coast of North America (Davidson and Hutchinson, 1938). The question of what species other than king salmon, *O. tshawytscha*, enter California's Sacramento and San Joaquin River systems has been confusing to scientists and sportsmen alike for many decades. One reason for this confusion is the abundance of literature in which reference is made to kings being the only salmon in the Sacramento and San Joaquin River systems, or the only salmon commonly seen there, while at the same time there have also been sporadic published and unpublished reports of the presence of other species. Another reason is that to date no one has made a detailed report describing the occurrence and abundance of salmon other than kings in the Central Valley.

During the past 25 years the California Department of Fish and Game has kept records of the annual numbers of king salmon spawning in most of the principal streams in the Central Valley (Fry, 1961). During the 10-year period 1949 through 1958 the authors made a sustained effort to identify salmon other than kings, to encourage others who were handling large numbers of salmon to do the same, and to keep accurate records of those positively identified. In the 10-year study period, 130 salmon other than kings, including all of the other four species, were taken and identified in the Sacramento River system; 119 of them were taken above Sacramento. They included chum, pink, sockeye, and silver salmon *(O. keta, O. gorbuscha, O. nerka,* and *O.*

[1] Submitted for publication June 1966.

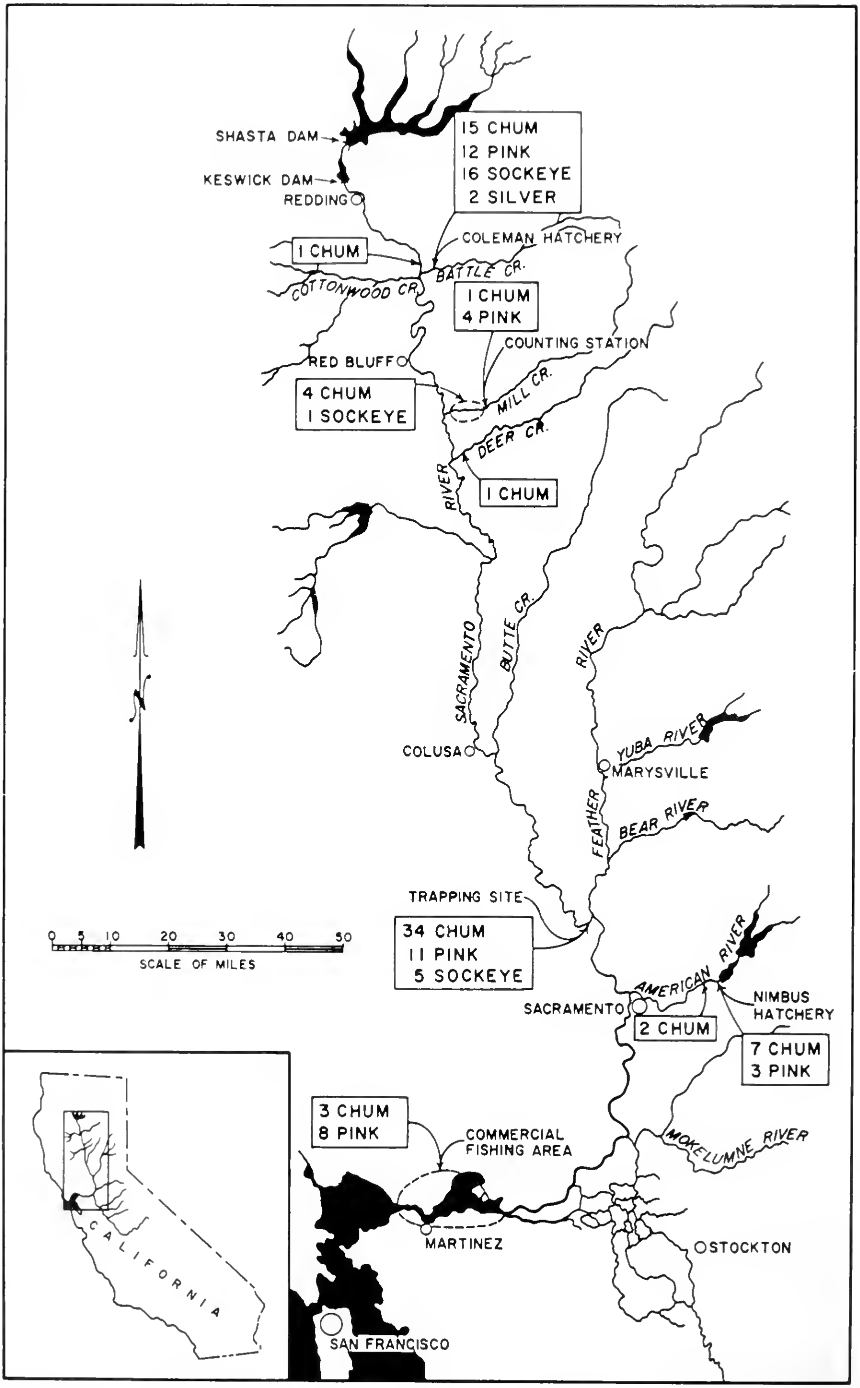

FIGURE 1—Sacramento River system, showing numbers and locations of chum, pink, and sockeye salmon taken from 1949–50 through 1958–59. Only those silver salmon taken before 1956 are shown. In that year planted silvers began returning to the river.

kisutch). In most instances they were noted among fall-run king salmon at counting stations, at fish hatchery traps, during salmon tagging studies, and while counting carcasses on spawning beds during annual population inventories. Eleven rare salmon (chums and pinks) were noted in commercial salmon landings from below the junction of the Sacramento and San Joaquin rivers during the same period. No unusual salmon were found in the San Joaquin River above the junction, in its tributaries, or in the Mokelumne River system. Thus, king salmon appear to be the only salmon reliably recorded from these other river systems in the Central Valley. Because of this, the chum and pink salmon recovered in the commercial fishery were considered to be Sacramento River fish.

The numbers of unusual salmon identified in the Sacramento River system do not give a true picture of their abundance, since they were found while sampling only a fraction of the total salmon present. Therefore, estimates were made of the total numbers of chums, pinks, and sockeyes which were present during the study period. Data were insufficient to permit a meaningful estimate of the numbers of silver salmon.

Data are also included on the estimated abundance of king salmon, which form over 99% of all salmon each year.

SPECIES OF SALMON

The species of salmon are listed in order of apparent abundance in the Sacramento River system, not in taxonomic order.

King Salmon, *Oncorhynchus tshawytscha* (Walbaum)

Distribution in North America and the Eastern Pacific

King salmon are found in the eastern Pacific Ocean from southern California to northwestern Alaska. Off the California coast, they are regularly caught in good numbers as far south as Monterey (lat. 36° 37′ N.), and in some years there is a fair fishery off San Luis Obispo County (to about lat. 35° N.). Kings are rare south of Point Conception (lat. 34° 27′ N.). In the early part of this century, the southernmost spawning in North America was by a small run in the Ventura River (lat. 34° 17′ N.), but at present the species spawns in suitable rivers from the Sacramento-San Joaquin river system to northwestern Alaska.

In California, kings are by far the most abundant species of salmon, but in North America as a whole they are the least abundant species.

Life History

King salmon are known to migrate farther into fresh water than any other salmon. They spawn over 2,000 miles from the sea in the Yukon River. In general, kings prefer the larger rivers but also enter some astonishingly small tributaries. A few relatively small coastal streams support runs of kings but as a rule these runs are small.

In California, most young king salmon migrate to the ocean during their first few months of life, but a few remain in fresh water until they are yearlings. In many California salmon rivers, summer temperatures are so high that in order to survive all young salmon must emigrate

before the water becomes too warm. Most king salmon mature at three or four years of age; two-year-old precocious males ("jacks") are also abundant. Five-year-old fish used to be common in California but now make up only a minor part of catches and spawning runs. Six-year-olds and yearling "jacks" are rare. North of California, five-year-olds are relatively more common and seven-year-olds are not unheard of. Kings are the largest of all Pacific salmon. Mature four-year-olds average a little over 20 pounds in weight. 40-pounders are not uncommon, and fish over 100 pounds have been recorded. Two-year-old "jacks" usually weigh about 3 pounds.

Occurrence in the Sacramento-San Joaquin River System

There are three basically different strains of king salmon in the Sacramento River system and two in the San Joaquin River system:

Fall-run fish are the most numerous. Most of these fish enter both rivers sometime between early September and early December, although many arrive either earlier or later than this. Fall-run fish reach peak spawning in November and December, and normally spawn relatively soon after they reach the appropriate part of the river. In general, fall-run fish enter the rivers after temperatures have begun to drop, and flows have started to increase. The timing of runs varies from stream to stream.

Spring-run salmon used to be abundant in the Central Valley but now relatively few streams support a spring run and most of the runs that still exist are quite small. The spring run enters a river in spring or early summer, during the time when the snowmelt usually supplies an adequate flow of cold water. The fish move upstream until they reach areas which normally remain cool in summer. Spawning takes place during early fall. On many Central Valley streams high dams have made it impossible for these fish to reach their ancestral spawning grounds, and below these dams low summer flows combined with high water temperatures have made it impossible for them to survive. Low stream temperatures below Shasta Dam have enabled a fair spring run to persist in the main Sacramento River, but they have become almost extinct in the San Joaquin River system.

Winter-run salmon are found only in the Sacramento River system, and about 98% spawn in the main stem of the Sacramento. The winter run usually reaches the upper river near Red Bluff in December and spends a relatively long period in the river before spawning. May and June are the principal spawning months. According to a theory advanced by Slater (1963), these fish are presumably descendants of a small run that formerly spawned in the McCloud River, a tributary of the Sacramento to which access has since been cut off by Shasta Dam. It is thought that a few fish survived the building of the dam, found temperatures and other conditions below the dam suited to their needs, and increased rapidly. The winter run is now considerably larger than the spring run.

Abundance in the Sacramento-San Joaquin River System

Detailed king salmon spawning escapement records presented in this paper cover only the period from 1953 through 1958. During this period, estimates of the size of the fall run for the entire Central Valley varied from a low of 117,000 in 1957 to a high of 597,000 in

1953 (Table 1). No satisfactory escapement records are available for winter- or spring-run salmon during these years. In a later period (1958 through 1963) Department of Fish and Game salmon spawning inventories show that the total fall run in the Central Valley averaged about 330,000 fish, the winter run perhaps 60,000, and the spring run about 28,000.

TABLE 1

Fall-Run King Salmon, Estimated Spawning Escapement
In Thousands of Fish
Sacramento-San Jocquin River System, 1953–54 Through 1958–59 Seasons *

	1953–54	1954–55	1955–56	1956–57	1957–58	1958–59
Grand total, all rivers	597	487	400	165	117	283
Total, Sacramento River and tributaries	513	412	369	153	102	237
Sacramento River Main Stem	408	276	231	94	68	128
Battle Creek†	16	12	26	21	5	29
Mill Creek	10	7	3	1	5	4
Deer Creek	4	3			2	1
Feather River	28	68	86	18	10	32
Yuba River	6	5	2	5	1	8
American River†	28	29	17	6	8	27
Other Sacramento River tributaries	13	12	4	8	3	8
Total, Mokelumne River and tributary	4	9	4	1	3	8
Cosumnes River	2	5	2	1	1	1
Mokelumne River	2	4	2		2	7
Total, San Joaquin River tributaries	80	66	27	11	12	38
Stanislaus River	35	22	7	5	4	6
Tuolumne River	45	40	20	6	8	32
Merced River		4				

Designates an escapement of 500 fish or less.
* From Fry (1961).
† Includes hatchery fish and natural spawners.

Chum Salmon, *Oncorhynchus keta* (Walbaum)

Distribution in North America and the Eastern Pacific

In the eastern Pacific Ocean, chum salmon have been found from near Del Mar in southern California (lat. 32° 57′ N., long. 117° 25′ W.)[2] to northwestern Alaska. There are recognized spawning runs in streams tributary to Tillamook Bay, Oregon, northward through Alaska and in the Arctic Ocean tributaries as far east as the McKenzie River, Yukon Territory, Canada. In California coastal streams, they have been reported from the San Lorenzo River (Scofield, 1916).

Chums do not form a measurable part of the California salmon catch, but in the entire North American salmon catch they usually rank third (behind pink and sockeye, and ahead of silver and king).

Life History

Most chum salmon spawn close to salt water, but some runs migrate considerable distances upstream. In the Sacramento River they have been found in spawning condition over 200 miles from the ocean. The

[2] Messersmith (1965).

TABLE 2

Chum, Pink, Sockeye, and Silver Salmon
Sacramento-San Joaquin River System, 1949–50 Through 1958–59 Seasons

	Earliest recorded date	Latest recorded date	Commercial fishing area[2]	Fyke traps Sacramento R. 1 to 2 mi. above Feather R.	Sacramento River near Battle Creek	Coleman N.F. Hatchery[3]	Mill Creek spawning grounds[4]	Mill Creek Counting Station	Deer Creek spawning grounds	American River, Nimbus Hatchery	American River near Fair Oaks	TOTALS
Chum Salmon												
1949–50	"Fall"	"Fall"				1					—	1
1951–52	Sept. 8	Nov. 14		2	1	2					—	5
1952–53	Sept. 15	Nov. 5	1	3		1			—		—	5
1953–54	Oct. 27	Jan. 4		1		2	2	1	1		—	10
1954–55	Aug. 10	Dec. 23	2	17		3	1				2	25
1955–56	July 21	Nov. 20		4		2	-				—	6
1956–57	Aug. 27	Dec. 21		2		2	1			2	—	7
1957–58	Fall	Fall				1			—		—	1
1958–59	Aug. 6	Feb.		2		1				5	—	8
Total			3	34	1	15	4	1	1	7	2	68
Pink Salmon												
1949–50	Fall	Fall				1					—	1
1951–52	Sept. 20	Sept. 20		1		2					—	3
1952–53	Sept. 9	Sept. 21		2		1			—		—	3
1953–54	Sept. 3	Nov. 10		4		1		3	—		—	8
1954–55	Nov.	Nov.				1			—		—	1
1955–56	Aug. 30	Oct. 11	8	3		6			—		—	17
1956–57	Fall	Fall								1	—	1
1957–58	Fall	Fall		1					—	2	—	3
1958–59	Oct. 26	Oct. 26						1	—		—	1
Total			8	11		12		4		3	—	38
Sockeye Salmon												
1949–50	Fall	Fall				1		—	—	—	—	1
1950–51	Fall	Fall				2			—		—	2
1951–52	Fall	Fall				3	—		—	—	—	3
1952–53	Fall	Fall				2	—		—	—	—	2
1953–54	Fall	Fall				2			—	—	—	2
1954–55	Sept. 7	Nov.		2		3	—		—		—	5
1955–56	Sept. 20	Sept. 25		—		2	—	—			—	2
1956–57	July 24	July 24		1	—	1	—	—	—	—	—	2
1957–58	Oct. 1	Oct. 1		—	—	—	1	—	—	—	—	1
1958–59	Aug. 11	Aug. 20		2	—	—		—	—	—	—	2
Total			—	5	—	16	1	—	—	—	—	22
Silver Salmon												
1949–50	Fall	Fall		—	—	1	—	—	—	—	—	1
1950–51	Fall	Fall	—	—	—	1	—	—	—	—	—	1
Total			—	—		2		—	—	—	—	2
Recap of totals												
Chum Salmon			3	34	1	15	4	1	1	7	2	68
Pink Salmon			8	11	—	12	—	4	—	3	—	38
Sockeye Salmon			—	5	—	16	1	—	—	—	—	22
Silver Salmon			—	—	—	2	—	—	—	—	—	2
Grand total			11	50	1	45	5	5	1	10	2	130

[1] Many fish entered hatchery ponds on an unknown date, were discovered later. These are referred to the appropriate month or season.

[2] In 1949, commercial salmon netting was permitted from Carquinez Strait to Rio Vista and in some of the lower San Joaquin Delta. Later, the area was reduced and in September 1957 was eliminated entirely.

[3] Coleman National Fish Hatchery received fish from Battle Creek and the Sacramento River. Except for king salmon, we could not determine which fish or how many came from each stream.

[4] Downstream from the counting station.

[5] Does not include planted silvers. Downstream migrating silver salmon yearlings were planted in Mill Creek in March 1956 and began returning that same fall.

young go to sea soon after emerging from the gravel, and maturity is usually reached in the fourth year of life. However, some may mature in the third or fifth year. At maturity, the average chum weighs about 10 pounds, with a maximum weight of about 30 pounds.

TABLE 3

Fork Lengths (mm) of Chum, Pink, Sockeye, and Silver Salmon
Sacramento-San Joaquin River System, 1949–50 Through 1958–59 Seasons

	Chum			Pink			Sockeye			Silver		
M = Male F = Female	M	F	Sex not known	M	F	Sex not known	M	F	Sex not known	M	F	Sex not known
	625	170	470	455	530	335	595	270	580	840		
	630	510	635	460		450		580				
	720	620	710	605		560						
	725	635	730	635		565						
	740	660	760			590						
	750	665	800			600						
	785	665										
	785	665										
	795	675										
	910	675										
		675										
		685										
		700										
		725										
		740										
Number of fish measured	10	15	6	4	1	6	1	2	1	1	0	0
Not measured	9	12	16	10	4	13	2	0	16	0	0	1
TOTALS	19	27	22	14	5	19	3	2	17	1	0	1
TOTALS	Chums: 68			Pinks: 38			Sockeyes: 22			Silvers: 2		

Occurrence in the Sacramento River

During the period of study, 68 chums were positively identified from the Sacramento River system. This includes catches made in the Delta (Tables 2 and 3). Of these fish, 34 were taken in the fyke traps which were operated in the Sacramento River near Fremont Weir, a short distance upstream from the mouth of the Feather River (Hallock, Fry, and LaFaunce, 1957), 15 were recovered at Coleman National Fish Hatchery on Battle Creek, 7 at Nimbus Salmon and Steelhead Hatchery on the American River, 3 from commercial salmon landings in the Delta, 1 at Mill Creek Counting Station in Tehama County, and 8 as spawned-out carcasses (4 in Mill Creek, 2 in the American River, and 1 each in Deer Creek and the Sacramento River).

Twenty-two of the chums taken in the fyke traps were tagged and released over a four-year period. Only two of these tagged fish were recovered. A male, 758 mm fork length, was tagged and released on November 3, 1953, and recaptured November 30, 1953, by department personnel on Mill Creek, a tributary some 140 miles upstream. The other was taken by a sportsman. Details could not be obtained.

Pink Salmon, *Oncorhynchus gorbuscha* (Walbaum)

Distribution in North America and the Eastern Pacific

Along the North American coast, pink salmon have been taken from La Jolla, California (Hubbs, 1946) to northwestern Alaska and eastward along the Arctic Coast to the McKenzie River, Yukon Territory. The southernmost American spawning runs of importance are in streams tributary to Puget Sound. Pinks are the most abundant North American salmon.

Off California, small catches of pinks are made in some years by salmon fishermen searching for king and silver salmon. Pink salmon have been recorded in several California coastal streams: Scofield (1916) reported that several had been taken in the San Lorenzo River in November 1915; Snyder (1931) reported them as present but rare in the Klamath River; Taft (1938) reported them as having entered Mad, Ten Mile, Garcia, and Russian rivers in 1937; Smedley (1952) recorded one in Prairie Creek, Humboldt County, in 1951; Roedel (1953) recorded pinks as spawning irregularly in some Mendocino County streams. On October 14, 1955, one of the present authors (Fry) watched pink salmon digging redds on one riffle in the lower part of the Russian River. At least six females were involved; there were males in the vicinity but not on the redds. Scofield (1916) reported several specimens from the San Lorenzo River. These records are in addition to those of the Sacramento River system, which will be discussed later.

Life History

On the average, pink salmon probably migrate shorter distances into rivers than any other Pacific salmon. Some pinks even spawn in tidal areas of streams at low tide, when the gravel is covered with fresh water. Although most pinks spawn within a few miles of salt water, there are some streams in which they travel considerable distances to reach spawning areas, such as those of Babine Lake on the Upper Skeena River in British Columbia. In the Sacramento River system, 12 pinks have been identified in Battle Creek, which is over 200 miles from the ocean.

Pink salmon are unique in that all individuals mature at the end of their second year. It follows that any stream which supports an annual run thus supports two independent populations. In many streams, there is a large spawning run one year followed by a small one the next, and sometimes one run or the other is nonexistent. In North America the southernmost pink salmon fisheries of importance land these fish in large quantities only in odd-numbered years. Most records of pinks in California have also been in odd-numbered years.

The pink salmon is sometimes known as the "humpback" because an exaggerated hump develops on the back of males between the head and the dorsal fin, as they near spawning condition. Pinks are the smallest of the Pacific salmon; they usually reach a weight of 3 to 6 pounds, and are occasionally as large as 11 pounds.

Occurrence in the Sacramento River

Jordan and Evermann (1896) reported that pinks were occasionally taken in the Sacramento River, where they were referred to as "Lost Salmon". Taft (1938) reported that a pink salmon was recovered in

Mill Creek (Tehama County) in 1933. Early records refer to an occasional pink being taken at hatcheries on the upper Sacramento River.

Many commercial gill-net fishermen who formerly fished for salmon in the Sacramento River have also fished for pink salmon in Alaska. These men recognize the species and some of them remember having taken an occasional pink in the Sacramento. Vincent Catania, a former Sacramento River gill-net fisherman now employed by the Department of Fish and Game, estimated that 30 years or so ago, in some seasons, the entire fishing fleet would take perhaps a dozen of these fish. Other fishermen recall the number as being higher than this.

In the period 1949 through 1958, 38 pink salmon were taken, identified, and recorded from the Sacramento River system. Twelve of these were from Coleman National Fish Hatchery, 11 were from fyke traps in the Sacramento River just above the mouth of the Feather River, 8 were taken by the commercial gill-net fishery (all in 1955), 4 were captured at the counting station on Mill Creek, and 3 were taken at Nimbus Salmon and Steelhead Hatchery on the American River (Tables 2 and 3).

Sockeye Salmon, *Oncorhynchus nerka* (Walbaum)

Distribution in North America and the Eastern Pacific

Sockeye salmon have been reported in the eastern Pacific Ocean from central California to northwestern Alaska. There are recognized spawning runs in suitable streams from the Columbia River northward to northwestern Alaska. Sockeye salmon are abundant off British Columbia and Alaska. In North America as a whole they are the second most abundant salmon.

Life History

Adult sockeye salmon usually ascend those rivers in which there are lakes. Some of them pass through the lakes and spawn in tributary streams, while others spawn along lake shores and in streams downstream from lakes. Relatively few sockeyes spawn in streams on which there are no lakes. A few young migrate to the ocean as fry immediately after emerging from the gravel, but the great majority spend between one and three years in a lake before descending to the sea. Those hatching upstream from a lake drop downstream into the lake, those which are hatched immediately below a lake move upstream into it, and those which hatch in a lake remain there. Sockeyes usually mature and return from the ocean to spawn at four or five years of age, but some mature at three, six, seven, or even eight years. The weight at maturity is usually 5 to 12 pounds, with a maximum of about 16 pounds.

Jordan and Evermann (1896) stated that sockeyes occurred in the Klamath River, and Scofield (1916) mentions that it was reported to him in 1916 that the commercial gill-net fishery at the mouth of the Klamath took 20 sockeyes. In contrast to these earlier reports, Snyder (1931) found nothing to substantiate the presence of even a stray sockeye in the Klamath in the 1920's. Before October 1917, salmon moving up the Klamath could continue as far as Klamath Lake and its tributary streams. On October 25, 1917, Copco Dam became a barrier that has since kept any salmon from reaching Klamath Lake. It is possible that the loss of this lake habitat was the final straw that led to the

extinction of sockeye salmon in the Klamath River. Taft (1937) reported a single sockeye taken in the Klamath River in 1936 and casts doubt on the identification of the fish reported to Scofield.

Occurrence in the Sacramento River

Twenty-two sockeye salmon were recovered and identified in the Sacramento River from 1949 through 1958 (Tables 2 and 3). There has been some speculation as to whether these were part of a remnant run, strays, or introduced kokanee salmon (the freshwater form of *Oncorhynchus nerka*) which had managed to migrate from lakes or reservoirs in the Sacramento-San Joaquin river system to the ocean, and were returning to spawn at maturity.

Kokanee were first introduced into California's inland waters in 1941 (Seeley and McCammon, 1963). By 1963, they had been stocked in 35 lakes. However, it was not until 1951 that they were stocked in lakes in the Sacramento River system. At that time, they were hatched and reared at Coleman National Fish Hatchery, from eggs taken in British Columbia, and released in Shasta Lake. Additional releases were made in Shasta Lake during 1952 and 1953. A large self-sustaining kokanee population developed rapidly in the lake.

It is probable that kokanee evolved from anadromous sockeye stocks where barriers to migration or other environmental changes caused conditions unfavorable to an anadromous existence. Apparently there are no structural differences between the two forms. The obvious differences of size and habit may be the result of environment rather than heredity.

It has been theorized that if kokanee were released where they had access to the ocean, some might migrate and return as sea-run adults. This phenomenon was actually demonstrated in Britsh Columbia, where sea-run sockeye were produced from kokanee reared and liberated as yearlings at Cultus Lake (Foerster, 1947). Fish passage studies by the U. S. Corps of Engineers at Shasta Dam showed that under favorable conditions fingerling salmonids passing through the turbines had a survival rate as high as 91% (Cramer and Oligher, 1964). The possibility that sockeye in the Sacramento River could develop from kokanee in Shasta Lake may account for some of the 22 sockeye recoveries made in the Sacramento River system, but it certainly does not account for all of them. Six of these 22 sockeye were recovered between 1949 and 1951; *i.e.*, before the first kokanee were planted in Shasta Lake.

Of the 22 sockeye recovered in the Sacramento River system, 16 were taken at Coleman National Fish Hatchery (Coleman spawns fish from Battle Creek and from the Sacramento River), 5 were taken in fyke traps in the main stem of the Sacramento, and 1 was recovered at Mill Creek Counting Station.

Silver Salmon, *Oncorhynchus kisutch* (Walbaum)

Distribution in North America and the Eastern Pacific

In the eastern Pacific Ocean, silver salmon have been found from about lat. 30° 50′ N., long. 116° 11′ W. (a few miles south of Cape Colnett, Baja California, Mexico) northward to northwestern Alaska (Messersmith, 1965). They are rare south of Monterey Bay. Silver salmon spawn in suitable streams from northern Monterey Bay, Cali-

fornia, northward to Alaska, but rarely enter the Sacramento-San Joaquin system, although there were and perhaps still are spawning runs in at least two small Marin County streams tributary to San Francisco Bay [3]. Silvers enter many small coastal streams that are not utilized by kings, but they are also found in many large rivers where kings do occur.

In California, silver salmon are of relatively minor importance—they constitute about 10% of the commercial catch and about 15% of the sport catch. In North America as a whole, silver salmon catches are exceeded by those of pinks, sockeyes, and chums.

Life History

Silver salmon may spawn a short distance from the ocean or they may proceed to the upper tributaries of the larger rivers.

Young silver salmon usually spend a little over a year in fresh water before migrating to the ocean; a few spend two years. This limits them to streams whose summer temperatures remain low enough for the young to survive. High summer temperature is probably an important factor preventing the establishment of silver salmon in streams of California's Central Valley (there may be other factors as well). Most silvers mature at the end of their third year. Under normal conditions, there are moderate numbers of two-year-old precocious males (grilse or "jacks"). Silver salmon older than three years are relatively rare. During their stay in fresh water, young silver salmon actively seek out stream areas which suit their needs and thus distribute themselves through the available watershed.

Mature silver salmon are normally between 6 and 12 pounds in weight and the maximum is about 30 pounds.

Occurrence in the Sacramento River

As previously mentioned, silver salmon (other than planted ones) have been the rarest of the five species of salmon in the Sacramento River system. From 1949 to 1956 (when they were introduced into the Sacramento) only two had been identified; both of these were taken at Coleman National Fish Hatchery. One was recovered in the fall of 1949 and the other in the fall of 1950 (Tables 2 and 3). One additional silver salmon was reported at Coleman before 1949 (John Pelnar, personal correspondence). It would seem safe to regard these three recoveries as strays rather than as remnants of a silver salmon run.

Introduction to the Sacramento River System

In March 1956 silver salmon were introduced into the Sacramento River system when 43,025 yearlings of Lewis River, Washington, stock were released in Mill Creek. These fish had been reared at the California Department of Fish and Game's Darrah Springs Hatchery on upper Battle Creek. The original plant was followed by 53,505 yearlings in February and March 1957, and 48,800 in April 1958; all were planted in Mill Creek.

Population estimates were made of returning silvers, using the Petersen method of tag and recapture. Calculated totals included a return

[3] These are Corte Madera Creek and Arroyo Corte Madera Del Presidio. The latter is often called Mill Valley Creek.

from the sea of 3,220 two-year-olds in the fall of 1956. This was followed by combined totals of 6,420 two- and three-year-old fish in 1957 and 11,600 in 1958. The introduced silvers scattered throughout the Sacramento River system when returning to spawn, but the greatest concentrations were in Battle Creek, the water in which they were reared until yearlings, and in Mill Creek, where they were planted. Returns were about equal in these two streams. No population estimates were attempted after 1958, but returns to Mill Creek and Coleman National Fish Hatchery, creel census studies, and examination of salmon carcasses on spawning beds indicate a rapid decline after the stocking ceased. By the fall of 1963, silvers were almost as scarce in the upper Sacramento River system as they had been before the introduction.

Apparently some of the introduced silver salmon strayed into the American River instead of returning to Battle Creek or Mill Creek. One ripe female appeared at Nimbus Hatchery in 1958 (a few introduced silver salmon "jacks" had been seen previously). There were no adult silvers at Nimbus Hatchery in 1959. Some silver salmon young were transferred from Coleman Hatchery to Nimbus and later planted as yearlings in the American River. Presumably, these were descendants of the introduced silvers which returned to Battle Creek. Ninety-nine adult silver salmon were reported as entering Nimbus Hatchery in 1960 and 87 in 1961. These fish were of small size and poor quality. Since that time, the American River has received no more silver salmon plants and the run has faded to practically nothing.

ESTIMATING THE NUMBERS OF CHUM, PINK, AND SOCKEYE SALMON IN THE SACRAMENTO RIVER SYSTEM

In the 10-year period during which data were collected, 130 salmon, other than kings, were identified in the Sacramento River or its tributaries. How many others entered the river? In an attempt to answer this question, two basically different methods were tried on chum, pink, and sockeye salmon and a third method on chums alone. Only two silver salmon were identified and no estimate of the total number of silvers appears in this paper.

Ratio of King Salmon Escapement to Kings Taken at Hatcheries and Counting Stations

Each year, thousands of salmon enter the two salmon hatcheries in the Sacramento River system. All of these fish are examined, and hatcherymen believe that there is little chance of unusual species of salmon being overlooked. If the total run of king salmon entering a spawning stream is X times the hatchery take from that stream, we might assume that the most probable number of salmon of each other species is also X times the hatchery take of that species. For this assumption to be valid, it is essential that the behavior of the various species be sufficiently similar to asure that the chance of an individual salmon entering a hatchery would be the same regardless of species. For example, a species that tended to spawn in the first suitable gravel might reach Coleman Hatchery in disproportionately small numbers. This or other differences in habits may affect the proportion of each species which reaches the hatcheries. Certainly, we cannot trust the method implic-

TABLE 4

Estimated Numbers of Chum, Pink, and Sockeye Salmon in the Sacramento River System Based on the Fraction of the Total King Salmon Runs Handled at Hatcheries and Counting Stations

	King			Chum		Pink		Sockeye	
	A	B	C	D	E	F	G	H	I
Location and year	Handled alive	Escapement from Fry (1961)	Fraction handled Col. "B" ÷ Col. "A"	Handled alive	Computed escapement Col. "C" × Col. "D"	Handled alive	Computed escapement Col. "C" × Col. "F"	Handled alive	Computed escapement Col. "C" × Col. "H"
Sacramento River plus Battle Creek									
1950	6,084	115,000	18.9	0	0	0	0	2	38
1951	14,348	87,000	6.1	2	12	2	12	3	18
1952	16,150	282,000	17.5	1	18	1	18	2	35
1953	19,291	424,000	22.0	2	44	1	22	2	44
1954	13,641	288,000	21.1	3	63	1	21	3	63
1955	15,843	257,000	16.2	2	32	6	97	2	32
1956	10,089	115,000	11.4	2	23	0	0	1	11
1957	10,734	73,000	6.8	1	7	0	0	0	0
1958	22,196	157,000	7.0	1	7	0	0	0	0
Total					206		170		241
Mean					22.9		18.9		26.8
Mill Creek									
1953	3,765	10,000	2.7	1	3	3	8	0	0
1954	2,901	7,000	2.4	0	0	0	0	0	0
1955	1,722	3,000	1.7	0	0	0	0	0	0
1956	131	1,000	7.6	0	0	0	0	0	0
1957	1,341	5,000	3.7	0	0	0	0	1	4
1958	1,140	4,000	3.5	0	0	1	4	0	0
Total					3		12		4
Mean					0.5		2.0		0.7
American River									
1955	7,439	17,000	2.3	0	0	0	0	0	0
1956	1,537	6,000	3.9	2	8	1	4	0	0
1957	875	8,000	9.1	0	0	2	18	0	0
1958	9,571	27,000	2.8	5	14	0	0	0	0
Total					22		22		0
Mean					5.5		5.5		0
Sum of means (rounded to nearest whole number)					29		26		27

Note that the means for each of the three areas covers a different time period.

itly, but it may give some indication of the population of the less common species.

Coleman Hatchery handles fish from Keswick Dam Fish Trap on the Sacramento River and from Battle Creek.[4] Nimbus Hatchery takes fish from the American River and Mill Creek Counting Station (now dismantled) took fish that were moving up Mill Creek.[5] By using the approach given in the preceding paragraph, the average run in all streams combined was calculated to be 29 chums, 26 pinks, and 27 sockeyes. The time period involved was 1950 through 1958 for Coleman Hatchery and less for the other two stations (Table 4).

No Estimates Made From Carcass Counts

In theory, the carcasses of unusual salmon examined during the annual spawning stock surveys could be used to estimate the total escapement of each species in a manner similar to that just described. Unfortunately, this did not work out in practice. When the ratio of kings to other salmon examined at hatcheries was compared with the same ratio for spawned-out carcasses in the same streams it became evident that the carcass counters were either missing salmon of unusual species or misidentifying them as kings. When the data on all species are combined into a single 2x2 chi-square test, the difference is highly significant ($P = < 0.001$). Part or all of this difference may be because it is not necessary to examine the carcasses as closely as it is the live fish, and because the carcasses may be fungus covered or badly decomposed.

Estimates From Fyke Trap Catches

Another method of estimating the total escapement of chums, pinks, and sockeyes involved the fraction of the total escapement taken by fyke traps in the Sacramento River. The purpose of these traps was to catch king salmon and steelhead trout *(Salmo gairdnerii gairdnerii)*, which were then tagged in the course of population estimates (Hallock, Van Woert, and Shapovalov, 1961). The gear also proved effective in the capture of the other species of salmon.

The first year for which we have satisfactory king salmon escapement figures for the entire Sacramento Valley is 1953. We also have steelhead escapements for the period 1953 through 1958. During this period, the traps took approximately 1 king salmon out of every 80 and 1 steelhead out of every 8 that went past the trapping site.

The traps proved to be highly size selective—most of the trapped king salmon were two-year-old "jacks". It seems probable that the high proportion of steelhead is due more to their smaller size than to species selection. Further verification of the size selectivity of this gear was provided by the hatchery-reared silver salmon which began migrating upstream past the trapping site for the first time in 1956. During the years 1956, 1957, and 1958, a total of 1,648 two-year-old silvers was taken in the traps. The total population of two-year-old silvers was computed to be 13,400—a ratio of 1 trapped out of every

[4] Unfortunately, we were not able to determine how many of the unusual salmon came from Battle Creek and how many from the Sacramento River. This introduces still another source of error, since the hatchery took the majority of the Battle Creek run but only a small fraction of the Sacramento River run.

[5] At the Mill Creek Counting Station, each fish was handled and it seems justifiable to assume that all unusual species were noted. Odd-appearing salmon which could not be readily identified were set aside for later study.

8.13 in the run. In 1957 and 1958, a total of 159 three-year-old silvers was taken out of a computed population of 7,840 three-year-olds—a ratio of 1 trapped out of every 49.3. The chums captured were about the size of three-year-old silvers; the pinks and sockeyes were smaller than three-year-old silvers but larger than two-year-olds.

Not only is there a problem of size selection by fyke traps but there is evidence which hints that there may be some difference in the fraction caught by species independent of size. From 1951–52 through 1958–59, the fyke traps took 34 chum salmon. Chums recovered farther upstream totaled only 22, a ratio of slightly over $1\frac{1}{2}$ to 1 in favor of the traps. In the same period, the traps took 11 pink and 5 sockeye salmon, compared with 16 pinks and 16 sockeyes recovered upstream—ratios of roughly $1\frac{1}{2}$ to 1 and 3 to 1 in favor of the upstream recoveries. By comparison with these upstream recoveries, the traps did much better with chums. This is the exact opposite of what one would expect if the selectivity of the traps favored small fish and depended on size alone. Obviously, this difference could be due to something besides species selectivity by the traps. For instance, there is much less chance of recovering fish which stay in the main stem of the Sacramento, compared with those which enter Battle Creek or Coleman Hatchery. The difference between species could be in preferred spawning areas and in the percentage recovered after spawning rather than in trap selectivity.

If we ignore the possibility of species selectivity and assume that the proportion of each species caught lies between that of two- and three-year-old silvers (*i.e.*, between 8 and 49 to 1), then for each species we can estimate a supposed maximum and minimum which we hope will bracket the true run size. For the period 1951–1959 the mean chum run calculated by this method is between 34 and 210, the mean pink run between 12 and 74, and the mean sockeye run between 5 and 31 (Table 5).

TABLE 5

Estimated Numbers of Chum, Pink, and Sockeye Salmon Sacramento River System Above the Feather River Based on Fyke Trap Catches

	Chum			Pink			Sockeye		
		Weighted fyke trap catch			Weighted fyke trap catch			Weighted fyke trap catch	
Year	Catch in fyke traps	catch × 8	catch × 49.3	Catch in fyke traps	catch × 8	catch × 49.3	Catch in fyke traps	catch × 8	catch × 49.3
1951–52	2	16	99	1	8	49	0	0	0
1952–53	3	24	148	2	16	99	0	0	0
1953–54	3	24	148	4	32	197	0	0	0
1954–55	18	144	887	0	0	0	2	16	99
1955–56	4	32	197	3	24	148	0	0	0
1956–57	2	16	99	1	8	49	1	8	49
1957–58	0	0	0	0	0	0	0	0	0
1958–59	2	16	99	1	8	49	2	16	99
Mean (of 8 years)		**34**	**210**		**12**	**74**		**5**	**31**
Mean 1953–56		**54**	**333**		**16**	**98**		**6**	**37**

Traps are more effective on small fish of a given species. From 1956–58, they caught approximately ⅛ of the two-year-old hatchery reared silver salmon which passed the trapping site. In 1957–58, they took only one three-year-old silver salmon out of every 49.3.

Estimation of Chum Population From a Single Tag Return

A method which could be used to estimate the number of chums involves use of the tagging data obtained while operating fyke traps in the lower Sacramento River. No pinks or sockeyes were tagged and no silvers were taken until introduced silvers started returning in 1956. Two chums were tagged in 1953, 16 in 1954, 4 in 1955 and 1 in 1956. Of these 23 fish, 1 was caught by a sportsman and thus became unavailable to be recovered by the hatcherymen or spawning survey crews. Of the remaining 22, 1 fish was recovered by the spawning survey crew in Mill Creek. During those same four years, 15 untagged chum salmon were recovered at Coleman Hatchery, or on the spawning grounds upstream from the trapping site.

The population was estimated by using a formula from Ricker (1958):

$$\text{Estimated population} = \frac{M\,(C+1)}{R+1}$$

$$= \frac{22\,(16+1)}{1+1}$$

$$= 187$$ for four years (1953-56) or an average annual run of 47 (rounded upward from 46.75).

In the above equation:

M = Effective number of tagged fish (22)

C = Number of tagged and untagged fish in sample (1 tagged + 15 untagged)

R = Tagged fish recovered in sample (1)

Calculating the spawning escapement for a total of 4 years on the basis of a single tag return is very bad statistics, but the estimated annual run of 47 does lie within the range of estimates by the other methods.

SUMMARY AND CONCLUSIONS

King salmon are abundant in the Sacramento and San Joaquin river systems of California. To determine the occurrence and abundance of salmon other than kings in the Central Valley, a continuing effort was made to record all such salmon that were encountered by fisheries workers. This study lasted from 1949 until early 1959.

During the 10-year period, 130 unusual salmon, including chums, pinks, sockeyes, and silvers, were found among king salmon at counting stations, at fish hatchery traps, on spawning beds, in commercial fish landings, and during salmon tagging studies. All were taken in the Sacramento River system or below the junction of the Sacramento and San Joaquin rivers. No salmon other than kings were found in the San Joaquin system above its junction with the Sacramento, or in the Mokelumne River system.

Data on the distribution, life history, and occurrence of the five species of Pacific salmon, and on their abundance in the Sacramento River system, are included.

King salmon make up over 99% of all salmon in the Central Valley. From 1953 through 1958, the size of the fall run varied from a low of 117,000 in 1957 to a high of 597,000 in 1953.

During the study period, 68 chum, 38 pink, 22 sockeye, and 2 silver salmon were taken and identified in the Sacramento River system.

Order of magnitude estimates of the numbers of chums, pinks, and sockeyes in the Sacramento River system during the study period were made by two methods; a third method was used on chums alone. When we used the ratio of king salmon escapement to kings taken at hatcheries, as a basis for computing the abundance of the less common species, it was estimated that for the nine-year period 1950 through 1958 the average annual runs were: chums 29, pinks 26, and sockeyes 27. By computing their probable numbers from fyke trap catches it was estimated that for the eight-year period 1951 through 1958 the average annual number of chums was between 34 and 210, of pinks between 12 and 74, and of sockeyes between 5 and 31. Computing the chum salmon population from a single tag return gave an average annual run of 47 fish from 1953 through 1956. All of these methods have serious statistical weaknesses.

It was concluded that chum, pink, and sockeye salmon enter the Sacramento River regularly enough to be regarded as very small runs, but that silver salmon, before they were introduced in 1956, were so scarce and so irregular that they should be regarded as strays.

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GRAY WHALE CENSUSES BY AIRPLANE IN MEXICO[1]

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Aerial censuses of the gray whale, *Eschrichtius gibbosus* (Erxleben), populations in the wintering waters in Mexico (from near San Diego to around Cabo San Lucas, with a few records from the shores of the Gulf of California), chiefly in and about the lagoons along the west coast of Baja California, from 1952 through 1964, yielded the following counts (counts plausibly explicable as too low in parentheses): 1952, 827; 1953, 912 and *731*; 1954, *(276)* and 1,315; 1955, *(584)*; 1956, *(960)*; 1957, *(631)*; 1959, 1,509; 1960, 1,455; 1961, *(959)*; 1962, 1,193; 1964, 1,581. When these explicably low counts are largely disregarded the following conclusions seem warranted: (1) higher counts after 1952 and 1953 suggest a growing population; (2) data for 1954–1964 suggest a leveling off of the population; (3) on assumption that about half the population was observed, the total population may be roughly estimated as about 3,000; (4) nearly identical low counts for 1952 and 1953 and high counts for 1959 and 1960 seem to refute the hypothesis that odd-year runs differ markedly from the even-year runs.

In the winter of 1946–47 we initiated an annual census of the eastern Pacific population of gray whales, *Eschrichtius gibbosus* (Erxleben), as they migrated past San Diego toward the lagoons of Baja California, Mexico, where all of the calves are born. Having continued this census for several years until others took over the project (Gilmore, 1960*a,b*; Rice, 1961), we began, in February 1952, an annual aerial census of this population. The census covered the coastline from San Diego southward to the Cape region of Baja California, at a time of year when almost the entire population winters there. From 1954 through 1957 the tally also included the small number of whales that winters along the eastern coast of Golfo de California (Gilmore and Ewing, 1954; Gilmore, 1958–1961; Gilmore and Mills, 1962; Gilmore et al., in press).

These aerial censuses were made with the aid and collaboration of Gifford C. Ewing, then on the staff of Scripps Institution of Oceanography. In addition to providing and piloting his plane, Dr. Ewing actively participated in the counts. His skill as a pilot, his intimate knowledge of the lagoon area, and his patience and dedication all contributed greatly to the thoroughness of the censuses (other aerial tallies are not comparable).

We accompanied Ewing on the February flights of 1952, 1954, 1959, 1960, 1961, 1962, and 1964. On the flights of 1959, 1960, 1962, and 1964 we were further assisted by several others (see footnotes to Table 1). Raymond M. Gilmore made the counts with Ewing in 1953 (closely following a trip made by Ewing and Andreas B. Rechnitzer), 1954, 1955, 1956, 1957. Thus, over the period 1952–1964 we have counts from 13 flights, including 2 each in 1953 and 1954 (but none in 1958 or 1963).

Some particulars regarding our trips of 1952 and 1954 and his trips

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TABLE 1

Counts of Gray Whales, from Airplane(s), from San Diego, California Southward

Details regarding flights of 1952 to 1957 were specified by Gilmore (1960a: 26–29). Later flights are discussed in text. The counts for 1954 to 1957 included a few whales on the east shore of Golfo de California.

Year of flight	Date of flight	Counters, with G. C. Ewing	No. of whales counted: Calves	Adults	Total
1952	II:16–20	C. L. and L. C. Hubbs	79	748	827[1]
1953	I:31–II:4	A. B. Rechnitzer	190	722	912[1]
1953	II:25–27	R. M. Gilmore	118	613	731[1]
1954	II:1–7	R. M. Gilmore	59	217	276[2]
1954	II:14–21	C. L. and L. C. Hubbs	227	1,088	1,315[3]
1955	II:26–III:3	R. M. Gilmore	148	436	584[4]
1956	II:14–17	R. M. Gilmore	138	822	960[5]
1957	II:27–III:3	R. M. Gilmore	98	533	631[6]
1959	II:20–26	C. L. and L. C. Hubbs[7]	286	1,223	1,509[8]
1960	II:18–21	C. L. and L. C. Hubbs[9]	244	1,211	1,455[10]
1961	II:25–27	C. L. and L. C. Hubbs	169	780	949[10]
1962	II:18–21	C. L. and L. C. Hubbs[11]	141[12]	1,052[12]	1,193
1964	II:20–24	C. L. and L. C. Hubbs[13]	209	1,372	1,581

[1] Total listed as 700 to 750 by Gilmore and Mills (1962: 27).
[2] Count not comparable with others, because incomplete (whole west coast north of Laguna San Ignacio was bypassed) and too early.
[3] Preliminary, approximate tally of 1,400 (200 calves and 1,200 adults) listed by Gilmore (1960a: 27) and by Gilmore and Mills (1962: 27).
[4] Very low count attributable to omission of Vizcaino breeding area in main survey, only partly compensated for by inclusion here of early (February 4) aerial count of 69 calves and 121 adults by Gifford C. Ewing, Fred B Phleger, and Robert Langford; lateness of count also involved.
[5] Low count attributable in part to omission of several areas, as detailed by Gilmore (1960a: 28). Berdegué (1956: 105) who, along with D. Day, participated in the census, gave the count as 134 calves and 814 adults (total 948), and making estimates of numbers missed in areas not covered, arrived at a grand total of 1,008.
[6] "The flight was made in good weather and provided excellent coverage" (Gilmore, 1960a: 29); because of the late date many whales had probably returned north.
[7] George E. Lindsay participated in this flight and assisted in the count.
[8] This high count was not mentioned by Gilmore and Mills (1962: 27).
[9] On the 1960 flight we utilized a second, smaller plane provided and piloted by Lawrence C. Kuebler, and in the counting were further assisted by George E. Lindsay, Laurence M. Huey, and others.
[10] Gilmore and Mills (1962: 27) listed about 1,400 for each of the 1960 and 1961 flights. The 1961 count was abnormally low due to unavoidable haste, less than optimal weather, and omission of parts of the coast.
[11] On the 1962 flight we again utilized the plane provided and piloted by Mr. Kuebler and were assisted by George E. Lindsay, Earle Stanley Gardner, and Eva Ewing.
[12] Calves were not distinguished from adults in all areas.
[13] On the 1964 flight we were further assisted by Theodore J. Walker, Robert W. Elsner, and Jean Filloux.

of 1953 to 1957 were presented by Gilmore (1960a: 25–29). Berdegué (1956) gave an account of the 1956 flight. Our 1954 trip was in a Cessna 180 plane, which was excellent for observation. The 1959 and 1960 trips were in a Grumman Super Widgeon G44 amphibian, also very serviceable. Beginning in 1961 Ewing flew a larger plane, an Aero Commander 500 A, which served well for census taking.

Several circumstances may have favored higher counts as the aerial censuses continued. Beginning in 1959, additional personnel participated (except for the unsatisfactory count in 1961). On two of the last four flights a second and smaller plane, provided and piloted by Lawrence C. Kuebler, not only carried more observers but increased the width of the effective band of observation without requiring as much zig-zagging as on a single-plane operation. Greater skill in piloting and in observing tended to increase the counts. However, it is thought that there was only a moderate bias toward higher counts, particularly since Ewing very early in the series developed notable skill in zig-

zagging his course along the coast to cover the band of migration (with occasional sorties beyond the limit of occurrence), and in circling over the lagoons just tightly enough to largely avoid either duplication or omission. Furthermore, the more complete and therefore more significant enumerations were made by the same personnel, and the two highest counts were made with a single plane.

Throughout our operations we stationed the prime observers in the pilot's and copilot's seats, so that both sides were scanned. Altitude was varied, so that a wide band was covered along the open coast and close-up observation was maintained in lagoons and other areas in which the whales congregated. Observations were usually recorded on tape, but a running tally was also maintained. Over the lagoons in which the whales abounded, adults were enumerated by hand tallies and the numbers of calves were jotted down by a third party as they were called out.

Sources of error in the aerial census as practiced do exist. In addition to factors favoring higher counts, visibility varied greatly with sea and wind state and with haze. To counteract these factors in and about Scammons Lagoon, where the greatest concentration of whales occurs, a count was usually made early in the day, when conditions for observation were best (once a count on a windy afternoon was followed early the next day by a much higher count, which was accepted). Counts made prior to mid-February or after February 27 are suspect, because the whale population seems to be at its height in the lagoons during the intervening period. In some years, few whales enter the lagoons before early February, and toward the end of the month the northward exodus seems to be underway. In fact, during the second half of February the last down-migrating stragglers meet the vanguard of the northward migrants along the open coast (both groups ordinarily proceeding without calves).

Despite these and other sources of error and variance, the summary data (Table 1 and Fig. 1) from the aerial censuses of the eastern Pacific gray whales appear to provide a significant basis for estimates of the population. When explicably low counts are disregarded, several conclusions regarding the population trend seem to be warranted.

(1) The initial low counts of 1952 and 1953, just before the high count of 1954, seem to confirm other indications that the population had not yet reached the level soon after attained. Early inexperience may explain in part, but we think in small part only, the lower counts on the first two censuses.

(2) The data for the 11-year period, 1954–1964, strongly suggest a leveling off (suggested by Hubbs, 1959) of the population increase.

(3) The nearly identical low counts for 1952 and 1953 and the similarity of the high counts for 1959 and 1960 seem to refute the hypothesis held by some observers (for example, Gilmore, 1958), that odd-year runs differ markedly in numbers from the even-year runs.

(4) On the assumptions that about half of the total population was observed in the area covered, and that almost all the individuals were concentrated in that area at the time of the counts, the entire population of gray whales in the eastern Pacific may be roughly estimated as about 3,000. Any major error in the admittedly rather intuitive estimate that about half of the population was observed on the flights should

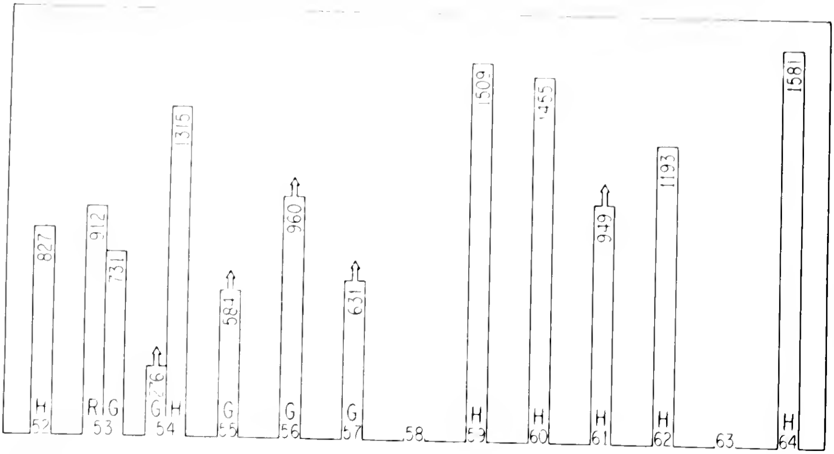

FIGURE 1—Aerial censuses of gray whales from 1952 through 1964, from San Diego southward. The figure at the base of each column indicates the year, the figure at the top is the number of gray whales observed, and the letter represents the person who, with Gifford C. Ewing, made the counts (G = Raymond M. Gilmore, H = Carl L. and Laura C. Hubbs, R = Andreas B. Rechnitzer). An arrow surmounting a column indicates an obviously incomplete count.

not markedly vitiate conclusion (2), because the counting was closely comparable, except as noted, from year to year.

Estimates of a population as high as 5,000 to 9,000 (Gilmore, 1960*a*,*b*, 1961; Rice, 1961) seem unrealistic to us, and news dispatches from Mexico giving an estimate of 15,000 seem unbelievable.

Higher estimates by American cetologists have been based either on the assumption that only about one-fourth of the whales were counted on the aerial surveys in Baja California, or on counts from the shore station at the Cabrillo National Monument on Point Loma, San Diego, California. We are inclined to believe that aerial surveys are somewhat superior to the shore counts (begun in 1946–47), as well as being much more economical of time (5 days versus 2 months). The shore counts involve uncertainties chiefly due to: (1) frequent periods of fog, which may occlude the view for as long as several days; (2) inability to observe movements at night, and lack of information as to the nocturnal conditions under which migration is continued or interrupted (we have observed that migration continues under bright moonlight but is fully suspended during dark of the moon); (3) very real difficulty in deciding how many whales are in a migrating gam (some observers have tended to count spouts).

A source of error in censusing from shore, which may be time-dependent, is a change in migration route (tending more offshore), and in evasive behavior, which may well have resulted from the increase of small-boat traffic along the shore and especially from the increase in the number of commercial and private boats that chase the whales during their coastwise migration to obtain a closer view. Recent observations (Rice, 1965) indicate a southward movement near the Channel Islands of California in excess of any we had previously observed in that area. The tendency of gray and other whales to exhale under water when disturbed and to expose only their blowholes for inhalation

(Hubbs, 1965) renders them difficult to see and count. These factors seem to have been responsible for the surprisingly low numbers of whales observed passing San Diego during the southward migration of 1963–64. Wondering if there might have been a sudden depletion of the whales due to disease, or to exploitation in the Arctic or in the western Pacific, we resumed the aerial census in February 1964 (after the planned termination in 1962). To our gratifying surprise, the counts from the airplane were slightly the highest yet obtained.

In this paper, no attempt has been made to detail the counts for each lagoon and for each coastal sector, nor to include observations on migrational route, behavior, etc. Further analysis of the voluminous field notes will probably slightly modify the total counts. We also have many years of observations from shore, from vessels and small boats, and from other plane trips and from helicopters. To date our observations have barely been summarized in print (Hubbs, 1959).

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SUMMARY OF THE 1963 AND 1964 SOUTHERN CALIFORNIA INSHORE BAIT FISHERY[1]

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Inshore bait species most commonly taken from intertidal areas are discussed. The distribution, method of catch, and the 1963 and 1964 catch statistics are summarized. In 1963, the commercial catch was 200,000 pounds, valued at approximately $100,000. The 1964 catch was 160,000 pounds and was worth $80,000. The most important species in terms of value to the fishermen were ghost shrimp and jack-knife clams.

INTRODUCTION

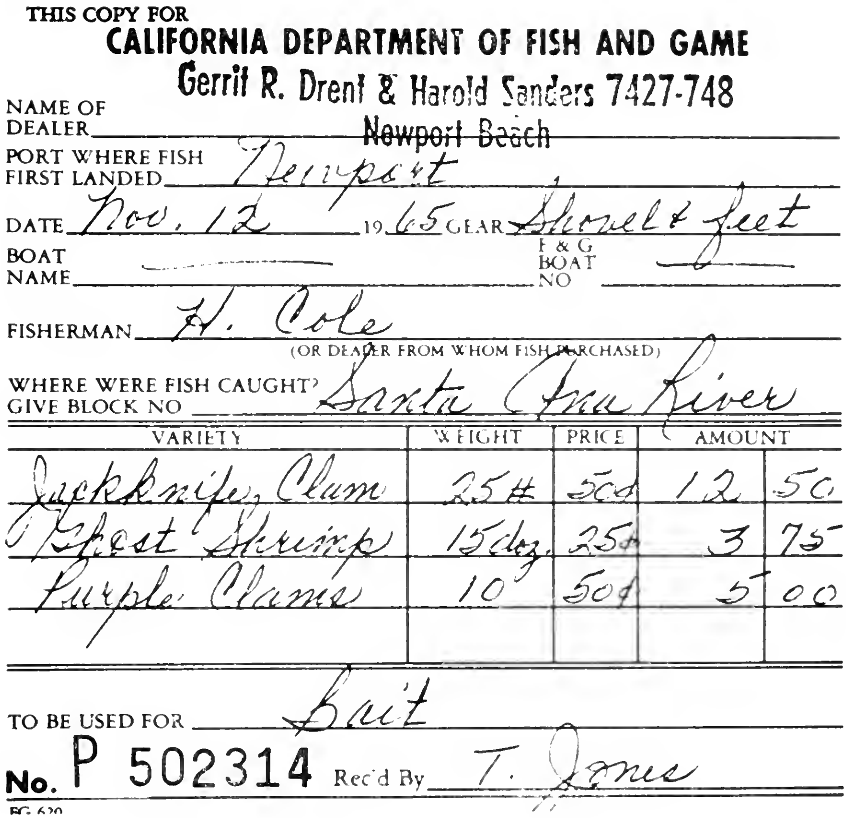
Californians enjoy many different recreational activities; one of the most popular is sport fishing. Annually, more than 1.6 million people purchase sport fishing licenses in the State. Approximately 50% of these fish in the ocean and bays at least once during the year and nearly 15% of them, as well as many pier fishermen and youngsters under age 16, who are not required to have a license, confine their fishing activities exclusively to the ocean (Abramson, 1963). These saltwater sportsmen expended an estimated $107 million for food, lodging, transportation, and fishing gear in 1963 (California Department of Fish and Game, 1965). An important aspect of fishing often overlooked is the universal need for bait.

The Department of Fish and Game has maintained catch records of the pelagic bait species for many years (California Bureau of Marine Fisheries, 1949). These records are from voluntary logs kept by live-bait boat skippers and receipts completed by wholesale fish dealers who purchase dead bait from fishermen. The live-bait catch is predominantly northern anchovies (*Engraulis mordax*), while the dead bait consists of anchovies, Pacific sardine (*Sardinops caeruleus*), Pacific herring (*Clupea pallasii*), squid (*Loligo opalescens*), and small amounts of Pacific mackerel (*Scomber diego*). Another segment of the bait industry deals with inshore benthic species. In 1962, the Department began gathering catch data on these inshore species, which previously had been ignored because they were assumed to be insignificant.

Source documents used for recording these data are furnished by the Department to all dealers purchasing bait from fishermen. These documents, sometimes referred to as sales slips or pink tickets (Figure 1), were designed before this fishery developed to its present extent. Some modification was necessary before the pink tickets could be used. Since this is generally a shore fishery, Department of Fish and Game boat numbers do not always apply and, in some instances, units of measure other than weight are accepted because of bait dealers' methods of operation.

During a pilot survey from June through December 1962, we assessed the magnitude of this inshore fishery and obtained data to convert the

[1] Submitted for publication April 1966.


THIS COPY FOR
CALIFORNIA DEPARTMENT OF FISH AND GAME
NAME OF DEALER Gerrit R. Drent & Harold Sanders 7427-748 ~~Newport Beach~~
PORT WHERE FISH FIRST LANDED Newport
DATE Nov. 12 1965 GEAR Shovel & feet
BOAT NAME —— F & G BOAT NO ——
FISHERMAN H. Cole
(OR DEALER FROM WHOM FISH PURCHASED)
WHERE WERE FISH CAUGHT? GIVE BLOCK NO Santa Ana River

VARIETY	WEIGHT	PRICE	AMOUNT	
Jackknife Clam	25 #	50¢	12	50
Ghost Shrimp	15 doz.	25¢	3	75
Purple Clams	10	50¢	5	00
/				

TO BE USED FOR Bait
No. P 502314 Rec'd By T. Jones
FG 620

FIGURE 1—An example of a completed receipt from a bait dealer.

various units of measure into pounds-in-the-round. These conversions, from dozens, gallons, and sacks into pounds-in-the-round, were established after numerous samplings of the landings at various bait shops to standardize the completed bait reports with our other published reports.

Species	*Conversion factor pounds-per-unit*	
Ghost shrimp	0.046	pounds per dozen
Mussel	80	pounds per sack
	3.8	pounds per shucked pound
	30	pounds per gallon
Sand crab	0.041	pounds per dozen
	4.5	pounds per gallon

Bait shop operators from Santa Barbara to San Diego were visited and those purchasing bait directly from fishermen were issued receipt books. Currently about 45 bait shops are completing receipts. Periodically each shop is visited by a biologist or a warden to resolve any questions that might arise. At present, approximately 25 fishermen participate in this fishery; about one-third fish only on weekends and holidays.

DESCRIPTION OF THE FISHERY

Species

The primary groups of organisms harvested by this fishery are mollusks and crustaceans. The six species that contribute most to the landings are jackknife clams (*Tagelus californianus*), purple clams (*Sanguinolaria nuttalli*), bay mussels (*Mytilus edulis*), sand crabs (*Emerita analoga*), ghost shrimp (*Callianassa californicus*), and red rock shrimp (*Hippolysmata californica*). Burrowing species (clams and ghost shrimp), inhabiting the mud of bays and estuaries, dominate the catch. Mussels, gathered from rocky areas and pier pilings along the coast and in bays, are also a major constituent of the harvest. There are many other kinds of baits available to the fisherman (Turner and Sexsmith, 1964) but these six species are the most important.

Bait Fishing Grounds

The southern California bait fishing grounds extend from Santa Barbara to the United States-Mexican border; however, fishing is concentrated in a few specific areas (Figure 2). Most catches are made in bays or estuaries, where extensive mud flats are exposed at low tide. These fishing grounds are usually accessible by road, precluding the necessity of a boat. Some of the best potential bait grounds are on military bases, such as the United States Naval Missile Testing Center at Point Mugu and the Seal Beach Naval Ammunition and Weapons Depot, and are closed to public access. Other baiting areas represent

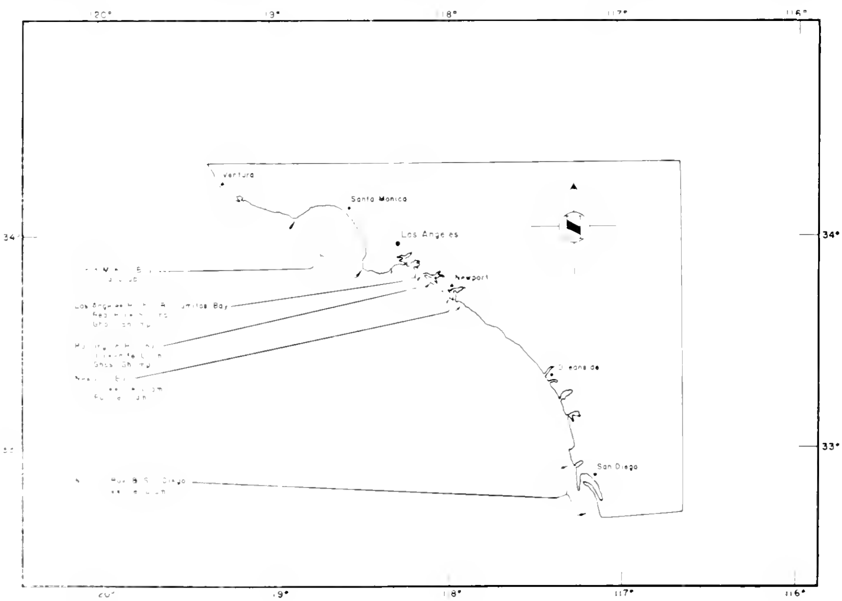


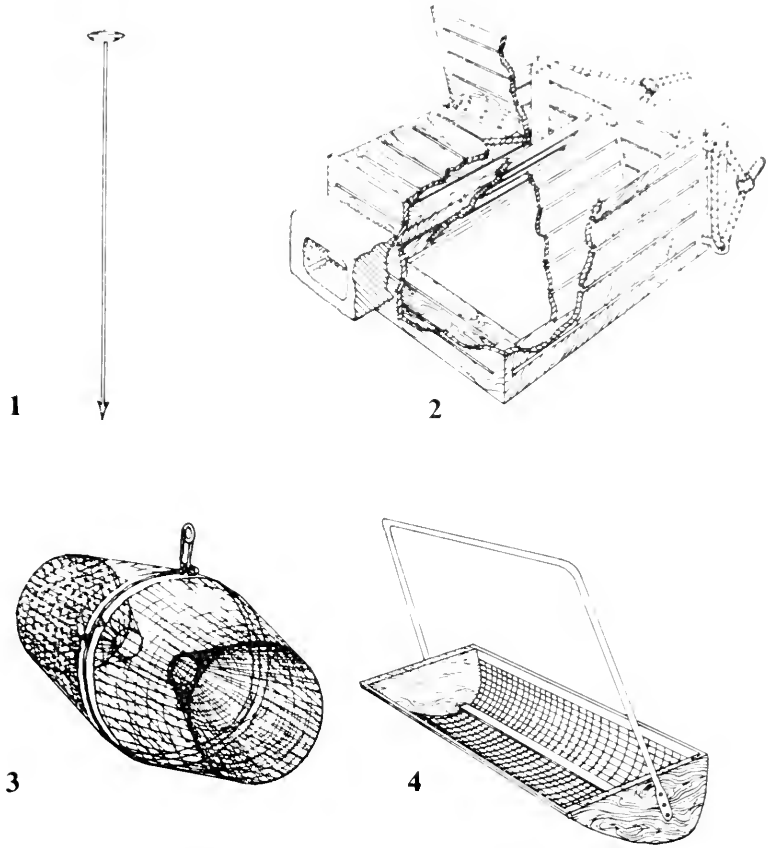
FIGURE 2—The southern California coast, showing the most important bait digging areas.

potential marinas or housing sites. In many instances where land development has occurred, irrevocable alterations and complete loss of habitat to many bait species have resulted. The "improved" portions

of Huntington Harbour are good examples of the effects of land development. Broad open mud flats have been changed to high and dry islands surrounded by deep channels.

Gear and Fishing Methods

Fishing gear (shovels, spears, rakes, grappling hooks, traps, and nets) varies according to the bait sought (Figure 3). With the exception of sand crabs and red rock shrimp, these baits are usually taken during low tide. Sand crabs are collected in a small wire-mesh net. The fisherman wades into the surf and places the net on the bottom as a wave commences to recede. The backwash carries the sand crabs into the net, from which they are removed and placed in a can hung from the fisherman's neck. Red rock shrimp are captured in baited traps placed on



1. Clam spear
2. Red shrimp trap
3. Minnow trap
4. Sand crab net

FIGURE 3—Examples of some of the gear used in the inshore bait fishery.

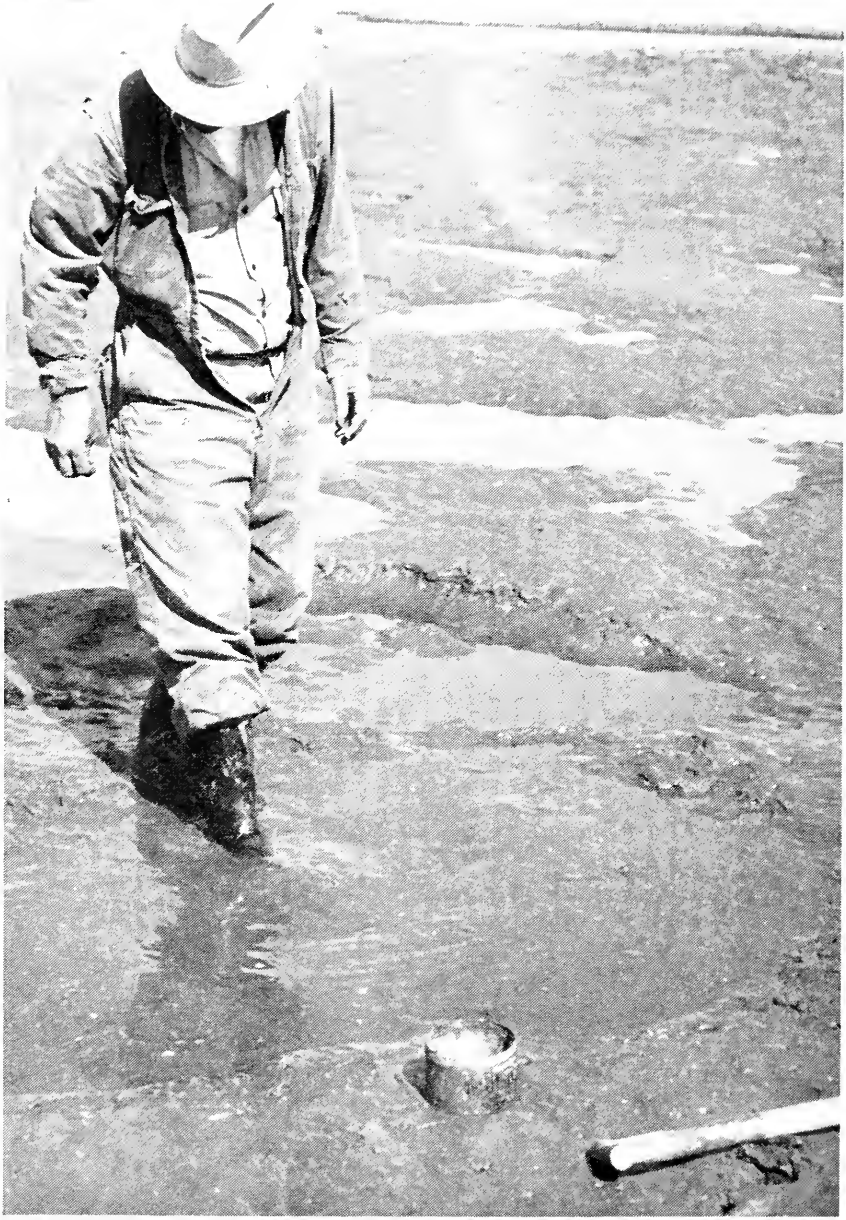


FIGURE 4. A commercial bait digger "stomping" for ghost shrimp in an undeveloped section of Huntington Harbour. *Photograph by the author.*

a rocky bottom near a breakwater or shore. The shrimp enter the trap through a fyke.

Clams are harvested with garden shovels or clam spears. The spear, used for jackknife clams, is inserted about a foot into the hole in the sand made by the clam's siphons and quickly rotated. The clam closes its shell around the spear, enabling the fisherman to pull it from the mud.

A shovel may be used to collect ghost shrimp, but the most common method is stomping (Figure 4). As the fisherman stomps the mud with his feet, the shrimps' burrows collapse and the animals move to the surface, where they are gathered. In July 1964 the Fish and Game Commission approved the use of a hand-operated hydraulic pump to take ghost shrimp in Los Angeles, Orange, and San Diego counties. This gear pumps water into the mud, flooding the shrimps' burrows, forcing the animals to the surface.

Mussels are usually gathered by hand; however, garden rakes, shovels, or grappling hooks may be employed to loosen them from rocks or pilings.

CATCH STATISTICS

During 1964, southern California's inshore bait fishermen landed nearly 160,000 pounds of bait valued at approximately $80,000. In 1963, the landings approximated 200,000 pounds worth $100,000.

DISCUSSION

Two years of data show this fishery to be one of moderate magnitude. The landings of approximately 180,000 pounds per year have a value to the fishermen of nearly $90,000. Approximately 25 fishermen and 45 bait shops are involved in catching and marketing inshore bait species. Most of the bait shops are between Malibu and Imperial Beach. Generally, they are grouped near fishing piers, around bays, or along the beaches which provide the most productive sport fishing.

The largest bait catches are made in Alamitos Bay, Huntington Harbour, the mouth of the Santa Ana River, Newport Bay, Mission Bay, and San Diego Bay. These areas account for about 85 percent of all bait landings. The remainder are taken along the coast and in other small bays from Santa Barbara to San Diego.

The current supply of inshore bait meets the demands of sport fishermen; however, this demand will grow as sport angling continues to increase because of population growth and increased recreational activities. The major problem facing this fishery is the loss of many prime fishing areas and inaccessibility of others. Some bays and mud flats are currently being modified to build new harbors and marinas. A great deal more knowledge is needed about the ecology of these species to minimize the deleterious effects of habitat modification. Areas within the boundaries of military reservations are closed to public access, and means of making these areas available should be considered.

TABLE 1

Inshore Bait Landings for 1963 and 1964: Pounds and Values by Area

	Los Angeles		San Diego		Totals	
Species	1964	1963	1964	1963	1964	1963
Jackknife clam	30,917 $16,282	40,657 $20,776	41,583 $20,420	32,403 $15,297	72,500 $36,702	73,060 $36,073
Ghost shrimp	3,526 $16,081	7,737 $33,126	1,173 $6,342	453 $2,924	4,699 $22,423	8,190 $36,050
Sand crab	4,896 $9,539	4,673 $11,919	5 $20	-	4,901 $9,559	4,673 $11,919
Mussel (bay and rock)	54,380 $4,974	85,260 $7,032	13,372 $1,283	19,858 $1,782	67,752 $6,257	105,118 $8,814
Red shrimp	-	-	-		2,446 $3,913	4,056 $6,382
Purple clam	2,115 $1,050	538 $269	2,271 $870	280 $140	4,386 $1,920	818 $409
Miscellaneous	15 $11	1,897 $891	408 $612	1,219 $572	423 $623	3,116 $1,463
Total	95,849 $47,937	140,762 $74,013	58,812 $29,547	54,213 $20,715	157,107 $81,397	199,031 $101,110

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STEMONOSUDIS ROTHSCHILDI, A NEW PARALEPIDID FISH FROM THE CENTRAL PACIFIC

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Tropical Atlantic Biological Laboratory [1]

A new species of paralepidid fish is described on the basis of a single specimen found in the stomach of a lancetfish (*Alepisaurus richardsoni* Bleeker). It is easily distinguished from other species of *Stemonosudis* on the basis of a long snout, a low number of dorsal and anal rays, and a striking color pattern.

The fish described here as a new species in the iniomous family Paralepididae was taken from the stomach of a Pacific lancetfish that was caught by longline in the central Pacific (Rothschild and Uchida, 1963), and supplied to me by Brian J. Rothschild, Bureau of Commercial Fisheries, Honolulu, Hawaii.

STEMONOSUDIS ROTHSCHILDI SP. NOV.

Holotype:

U. S. National Museum No. 199087, juvenile, 107 mm SL. From the stomach of a specimen of *Alepisaurus richardsoni* 460 mm SL, caught on longline gear from the U. S. Bureau of Commercial Fisheries R/V *Charles H. Gilbert* at lat. 22° 47′ N., long. 150° 09′ W. on February 15, 1963.

TABLE 1

Comparison of Morphological Characters of *S. rothschildi* and All Other Species of *Stemonosudis*

Character	*S. rothschildi*	All other *Stemonosudis* spp. from Rofen, 1966
Color:		
Dorsal blotches in advance of dorsal fin	5	0 to 3
Ventral blotches in advance of anal fin*	4	0 to 2
Vertical bands posterior to the dorsal fin	3	0 or 1
Meristic:		
Dorsal and anal rays	9 and 33	13 and 30 or 7 to 9 and 35 or more
Morphometric: (Percentage of standard length)		
Head length	20.6	14.7-18.3
Snout length	11.1	6.7-10.3
Premaxillary length	10.3	6.8- 9.6
Predorsal length	72.8	58.3-68.0
Distance between dorsal and anal fin	5.2	9.6-17.5

* These blotches are superficial and not to be confused with peritoneal pigmentation.

Diagnosis:

A *Stemonosudis* differing from the other species of the genus by a distinctive color pattern and several meristic and morphometric characters (Table 1).

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FIGURE 1—*Stemonosudis rothschildi*, holotype, USNM 199087, juvenile 107 mm SL. *Drawing by Grady Reinert.*

Counts and Measurements:

The specimen has several badly torn areas, and is twisted and distorted. Therefore, many of the measurements and the counts of the lateral-line sections and the vertebrae are unreliable. Dorsal rays 9 (all rays counted); anal rays 33 (all rays counted); pectoral rays 12 on each side; pelvic rays 8 on each side; approximately 109 scale-like lateral-line sections; approximately 90 vertebrae. Proportional measurements in thousandths of the standard length: body depth 61; caudal peduncle length 40; caudal peduncle depth 21; distance from snout to vent 617; head length 206; snout length 111; eye diameter 24; interorbital width 24; upper jaw length 103; predorsal length 728; length of dorsal fin base 30; pelvic fin origin to dorsal fin origin 148; dorsal fin origin to anal fin origin 52; tip of snout to origin of anal fin 742; length of anal fine base 176; pectoral fin length 145; prepelvic length 574; pelvic fin length 57; dorsal adipose fin origin to caudal base 62.

Description:

Lateral-line scales, body scales, and scale pockets not discerned. Lateral-line sections bony, typical of the genus. Ventral carina moderately developed; no dorsal carina visible. Two ventral adipose fins (may be remnants of a single damaged fin) in advance of anal fin; one dorsal adipose fin in advance of caudal fin.

Anterior portion of premaxillary bone with small hooked teeth curving posteriad; posterior portion with similar teeth curving mediad. Large, posteriorly curving, fang-like teeth on each side of palatine bones. Two large, fang-like replacing teeth ("depressible") prominent on each palatine bone. Each dentary bone with a single row

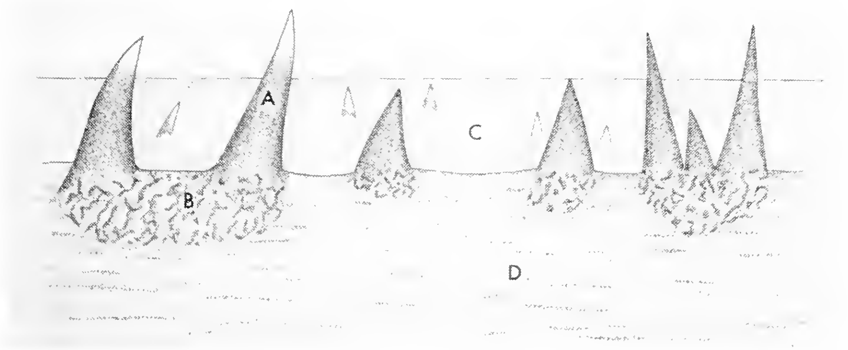

FIGURE 2—Section of the first gill arch of the holotype showing (A) gill tooth; (B) tooth platelet; (C) mucosa; and (D) gill arch. *Drawing by Grady Reinert.*

of six erect fangs and an inner row of four replacing teeth ("depressible") curving posteriad. Tongue and prevomer toothless.

Gillrakers (gill teeth) in one row on gill arch, mostly in pairs; each pair on a separate tooth platelet (Figure 2B). Replacing gill teeth present in mucosa of a gill arch stained with Alizarin Red S (Figure 2); teeth stained deeply, but showing no apparent replacement pattern. Fixed teeth also stained deeply (Figure 2A) except at tips, in platelet (Figure 2B), and in gill arch.

Coloration:

The striking feature of this species is the bold, dark color pattern. Six dorsal and four ventral blotches anterior to the anal fin; and three wide bands (the anteriormost divided dorsally) posterior to the anal fin origin. These blotches and bands are formed by heavy concentrations of dark pigment near the surface of the skin. Seven or eight smaller peritoneal blotches lying deeply along ventral body wall. Damage to the specimen (not shown in Figure 1) prevents accurate determination of the number of these deep-lying blotches, or whether the third and fourth dorsal blotches are entire. Remainder of body clear except for very small scattered chromatophores in region of lateral line and near fin bases.

Pectoral fin rays with scattered chromatophores. Dense concentrations of chromatophores present on interradial membranes starting about $^1/_5$ distally from base, but becoming faint on distal $^1/_5$ of fin; thus, middle portion of fin very dark. Pelvic fin rays with dark chromatophores scattered along their entire length; interradial membranes with very dark concentrations of chromatophores throughout their length.

Anterior ventral adipose fin heavily scattered with dark chromatophores; posterior one clear. Dorsal adipose fin with heavily scattered, dark chromatophores.

Dorsal fin rays heavily pigmented with evenly spaced dark chromatophores; interradial membranes pigmented as with pelvic fins. Anal fin pigmentation similar to that of dorsal, but only 5th through 12th interradial membranes heavily pigmented. Caudal fin rays, broken off short in the specimen, with a few chromatophores on basal portions; none on remnants of distal portions.

Head with various-sized chromatophores most heavily concentrated on ridges and edges of bones of snout, on premaxillary bone, and over brain.

Species Associates:

Other fishes found in the lancetfish stomach with *S. rothschildi* include: one *Sternoptyx diaphana* Hermann, 20 mm SL; one *Pteraclis velifer* (Pallas), head missing; one *Ranzania laevis* (Pennant), 9.7 mm SL; and one post-larval flatfish (Heterosomata), 20 mm SL.

Relationships:

S. rothschildi is referred to *Stemonosudis* because it conforms to the following diagnostic characters of that genus (Harry, 1953*a*,*b*; Rofen, 1966): more than 24 anal rays; 84–121 vertebrae; short pectoral fin; naked head and body; snout to vent length 61.7% of standard length; elongate body; dorsal fin originating well behind middle of body; anterior lateral-line sections longer than high; and nostrils anterior to posterior tip of maxillary.

Knowledge of the species of *Stemonosudis* is so incomplete—a number of the species, including *S. rothschildi*, are known only from juvenile and or larval stages—that comments on interspecific relationships are impractical. Superficially, at least, *S. rothschildi* does not seem to be closely related to any of the other species. The characters used here to

separate *S. rothschildi* from the other species (Table 1) do not significantly change with age in those species which are known from comparable and smaller sizes (Marshall, 1955; Ege, 1957).

ACKNOWLEDGMENTS

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Calif. Fish and Game, 53 (1): 40–48, 1967.

HARVEST, MORTALITY, AND MOVEMENT OF SELECTED WARMWATER FISHES IN FOLSOM LAKE, CALIFORNIA[1]

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Tagging studies of six warmwater game fish species at Folsom Lake indicated low annual harvest and high survival rates for ictalurids and high annual harvest and low survival rates for centrarchids. Possible errors in these estimates are discussed. Centrarchids moved considerably less than the ictalurids during their time at large.

INTRODUCTION

A tagging study was initiated in April 1962 to determine fishing and natural mortality rates of the more important game fishes in Folsom Lake. The primary reason for obtaining this information was to determine whether anglers were efficiently harvesting existing fish populations. The following species were tagged: largemouth bass, *Micropterus salmoides;* smallmouth bass, *M. dolomieui;* bluegill, *Lepomis macrochirus;* red-ear sunfish, *L. microlophus;* white catfish, *Ictalurus catus;* and brown bullhead, *I. nebulosus*. This study was part of a broad investigation of the Folsom Lake fishery. A description of Folsom Lake, a 10,000-surface-acre fluctuating reservoir, and other aspects of its fishery have been given by C. E. von Geldern (MS) and Tharratt (1966).

METHODS

Tagging Operations

All fish were tagged with disk-dangler tags (modified Atkins tags). These tags have proven to be efficient for largemouth bass (Kimsey, 1956; LaFaunce, Kimsey, and Chadwick, 1964); striped bass (Calhoun, 1953); channel catfish (McCammon, 1956); and white catfish (Pelgen and McCammon, 1955). Tags were made of cellulose nitrate disks 0.040 inch thick and either 1 cm or ½ inch in diameter. The smaller tags were used on centrarchids and the larger ones on ictalurids. Tags were attached with tantalum wire 0.020 inch in diameter. Tags were placed midway between the first dorsal fin and the lateral line under the longest spine, using the technique described by Chadwick (1963). Ictalurids were tagged similarly under the dorsal spine.

Numbered tags inscribed "$5 REWARD, California Fish and Game, Sacramento, Calif." were placed on 50% of the tagged largemouth bass, bluegill, and white catfish. The remaining 50% of these species and all the other species bore tags which offered no reward. The tag numbers and the lengths of the fish which bore them were recorded.

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Tagged fish were captured with seines, electrofishing apparatus, Oneida traps, and fyke nets (Table 1). Most of the centrarchids were captured by electrofishing at night. Catfishes were caught primarily in entrapment gear.

Generally, fish caught by electrofishing were held overnight in live cars and tagged the following day in the vicinity of capture. Fish caught in seines and entrapment gear were tagged immediately at the site of capture.

Centrarchids were tagged from April 26 through June 20, 1962. Ictalurids were tagged from April 26 through August 24, 1962. Most of the centrarchids were tagged in April and May. Catfishes were tagged primarily from June through August (Table 1). Actual tagging operations were discontinuous, and there were periods of two weeks when no tagging was done.

TABLE 1

Number of Fish Caught by Various Methods and Their Month of Capture

	Largemouth bass	Smallmouth bass	White catfish	Brown bullhead	Bluegill	Red-ear sunfish
Oneida trap						
April			[illegible]	56	2	
May			10	38	5	1
June			113	41	1	3
July			136	92		
August			80	6		
Total			348	233	8	4
Fyke net						
April			1	18	15	1
May			4	0		
June		1	16	1	3	
July			20	43		
August			42	40		
Total		1	83	102	18	1
Electrofishing						
April	[illegible]	12	1	12	[illegible]	[illegible]
May	182	1		3	44	11
June	6	1		1		
Total	451	14	1	16	133	50
Seine						
April		1	--			
May				-	1	1
June	9	7	8		18	6
Total	9	8	8	-	19	7
Grand totals	460	23	440	351	178	62

Posters advertising the program were placed in conspicuous places around the lake. Posters and franked envelopes were placed at all state park entrances, at the only marina, and at other local businesses. In addition, project personnel contacted many anglers while creel censusing, which further helped to advertise the program. Commendation cards were awarded to all anglers returning tags, and rewards of $5 were given to anglers who returned reward tags.

Mortality Computations

First-year tag returns include all tags returned from fish caught from 0 through 365 days after the date of tagging. Second-year returns are those recaptured from 366 through 730 days after the date of tagging.

Harvest and mortality notations and computations follow Ricker (1958). Only reward tags were used to calculate these parameters for largemouth bass, bluegill, and white catfish. Nonresponse for these fish was used to correct return data for the other species.

RESULTS AND DISCUSSION

Largemouth Bass

General Data

Tagged largemouth bass averaged 11.8 inches fork length and ranged from 9.0 to 21.0 inches (Table 2).

During the two-year study period anglers returned 119 (51.7%) of the largemouth bass reward tags. Anglers returned 111 reward tags in the first year, but only 8 during the second year. The low numbers of second-year returns indicate that returns were essentially complete.

Movement and "Time at Large"

The largemouth bass moved very little. The average distance from the point of tagging to the point of recapture was 0.7 mile. This mileage represents the shortest straight-line distance by water to the point of recapture as reported by the angler. The longest journey was 6.0 miles. Anglers caught 63% of the tagged bass less than one mile from the point of tagging.

TABLE 2

Length Frequency, Mean Length, and Range of Lengths of Fish Tagged—Folsom Lake, 1962

Length class[1]	Largemouth bass	Smallmouth bass	White catfish	Brown bullhead	Bluegill	Red-ear sunfish
6.0- 6.9		--	-	--	73	11
7.0- 7.9		--	-	--	47	15
8.0- 8.9	-	-	77	6	53	27
9.0- 9.9	81	2	120	21	5	8
10.0-10.9	142	10	81	83	--	1
11.0-11.9	77	9	50	119	--	--
12.0-12.9	31	0	53	66	--	--
13.0-13.9	36	2	27	46	--	--
14.0-14.9	40	--	18	10	--	--
15.0-15.9	26	--	9	--	--	--
16.0—	24		5	--	--	--
Total	460	23	440	351	178	62
Mean length (inches)	11.8	11.0	10.8	11.6	7.4	8.0
Range (inches)	9.0-21.0	9.8-13.8	8.0-17.5	8.0-14.8	6.0-9.5	6.0-10.0

[1] Fork length in inches.

Anglers returned 51 (43%) of the total reward tags within 15 days after tagging. Eighty-nine (75%) of this same total were returned within 60 days. Kimsey (1957) found a similar pattern of returns at Clear Lake, California.

Survival, Mortality, and Harvest

First-year reward tag returns indicate an exploitation rate of 0.48. Survival rate between the first and second year amounted to 0.07. Both values are probably inaccurate.

One source of error came from abnormal returns from one group of 64 fish which were held in live cars for two days, then tagged and released on Saturday morning in an area receiving heavy angling pressure. I observed five of these fish in the catch during the first weekend, and anglers caught 44 (69%) during the first year. This return is higher than the returns from other groups ($\chi^2 = 16.0$; $\chi^2_{0.95,\ 3\,d.f.} = 3.8$). Because of the extremely high return rate, this group was eliminated from further calculations.

The estimated exploitation rate then becomes 0.40 (Table 3). Since returns from all groups other than the one aberrant group were similar, and returns from disk-dangler tags have apparently given reliable measures of largemouth bass exploitation rates in the past, this estimate is probably accurate and appears most useful.

TABLE 3

Largemouth Bass Annual Survival, Mortality and Harvest Rates from Selected Waters

Lake name		a	u	v	Source
Clear Lake	0.44	0.56	0.20	0.36	Kimsey (1957)
Sutherland Reservoir	0.30	0.70	0.36	0.34	LaFaunce et al. (1964)
Folsom Lake	0.11	0.89	0.40	0.49	Present study
TVA Reservoirs			0.42, 0.41		Chance (1955)
Gladstone Lake	0.40	0.60	0.15	0.45	Maloney, Schupp, and Scidmore (1962)
Sugarloaf Lake	0.30	0.70	0.26	0.44	Cooper and Latta (1954)

s annual survival rate
a annual mortality rate
u expectation of death due to fishing (rate of exploitation, harvest)
v expectation of death due to natural causes

The adjusted first-year survival is 0.11. Intuitively, this seems unreasonably low. The most probable source of error is a change in exploitation and/or natural mortality rates during the two years. These were important at Sutherland Reservoir (LaFaunce et al., 1964). Since no tagging was done at the beginning of the second year, there is no way to detect or correct it. As a consequence, the estimate's precision is not known. However, C. E. von Geldern (MS) in 1962 found that 71% of the angler-caught bass were less than 14 inches long, indicating that survival was indeed low.

These facts point to a lower survival rate at Folsom Lake than survival rates reported for other lakes (Table 3). The exploitation rates compare favorably to both Sutherland and the two TVA lakes (Table 3).

A chi-square test demonstrated that reward tags from fish grouped in one-inch length intervals, when tagged, did not return at significantly different rates ($\chi^2 = 7.86$; $\chi^2_{0.95,\ 7\,d.f.} = 14.07$). This suggests that all largemouth bass over 9 inches long were equally vulnerable to the fishery.

Smallmouth Bass

General Data

The mean fork length of smallmouth bass was 11.0 inches. They ranged from 9.8–13.8 inches (Table 2).

Twenty-three smallmouth bass were tagged with nonreward tags. Thirteen tags were returned in the first year; none in the second year. Returns are considered complete.

Movement and "Time at Large"

The seven fish for which anglers reported recapture localities accurately, moved an average of 0.7 mile from the point of tagging, suggesting that smallmouth bass also move only short distances.

Of the 11 fish for which an accurate date of capture was supplied, 5 were captured within 45 days after tagging. The earliest recapture was 6 days after tagging; the latest was 346 days after tagging.

Survival, Mortality, and Harvest

Since so few fish were tagged, mortality rates can not be estimated, but the high percentage of first-year returns suggests an exploitation rate as high or higher than that for largemouth bass.

White Catfish

General Data

The mean fork length of the white catfish tagged was 10.8 inches. They ranged from 8.0–17.5 inches (Table 2).

During the two-year study period, anglers returned 65 (30%) of the white catfish reward tags. They returned 42 reward tags in the first year and 23 in the second year. Significant numbers of tags will probably be returned in the future.

Movement and "Time at Large"

White catfish are greater wanderers than largemouth or smallmouth bass. The mean shortest straight-line distance traveled was 2.3 miles from the point of tagging to the point of capture by anglers. Anglers reported catching them as far as 10.4 miles from point of tagging. Anglers reported catching only 7 catfish less than 0.5 miles from point of tagging. Ten recaptures were made more than 5.0 miles from point of tagging. Two white catfish were returned from Lake Natoma downstream from Folsom Lake after presumably passing through the dam. Unlike the largemouth and smallmouth bass, the first tagged catfish did not enter the catch until 20 days after tagging. Only 8 fish were returned in the first 90 days.

Survival, Mortality, and Harvest

None of the systematic errors described by Ricker (1958) were evident in the white catfish study. Catfish apparently distributed themselves randomly throughout the population and showed no indication of differential vulnerability between the two years.

Survival and exploitation rates of 0.55 and 0.19, respectively, at Folsom Lake followed closely those reported for other Californian waters (Table 4). These high survival rates coupled with low fishing and natural mortality rates indicate that white catfish probably are underexploited in most Californian waters. The catch could be increased by opening more areas to night fishing.

A chi-square test revealed that no statistically significant difference existed between the size of the catfish when tagged and the size, when tagged, of catfish from which tags were returned ($\chi^2 = 3.04$; $\chi^2_{0.95,\ 7\,d.f.} = 14.07$). Thus, all tagged fish were equally vulnerable to the fishery. Pelgen and McCammon (1955) and McCammon and Seeley (1961) reported a higher vulnerability for fish over 8.5 inches and 10 inches, respectively. Neither of these last two studies offered substantial rewards for the return of tags and did not measure nonresponse by size. Folsom Lake returns of nonreward tags as tested by chi-square showed a significant difference ($\chi^2 = 7.56$; $\chi^2_{0.95,\ 1\,d.f.} = 3.84$) between returns of fish above and below 10.0 inches long (Robert R. Rawstron, MS). Therefore, their reported differential vulnerability may actually have been due to differences in reporting returns from various sizes of fish.

TABLE 4

Survival and Mortality Rates of White Catfish from Californian Waters

Lake name	s	a	u	v	Source
Folsom Lake	0.55	0.45	0.19	0.26	Present study
Clear Lake	0.81	0.19	0.10	0.09	McCammon and Seeley (1961)
Delta	0.43-0.50	0.50-0.57	0.15-0.33	0.24-0.35	Unpublished
Delta			0.17	-	Pelgen and McCammon (1955)
Pine Flat Lake			0.08		Unpublished

Brown Bullhead

General Data

Tagged brown bullhead averaged 11.6 inches FL and ranged from 8.0-14.8 inches (Table 2).

Anglers returned 41 nonreward tags during the two years. Twenty-seven were returned in the first year and 14 in the second. Returns are not considered complete.

Movement and "Time at Large"

Like white catfish, brown bullhead appeared to move longer distances than largemouth bass. The mean shortest straight-line distance from point of tagging to point of capture as reported by the anglers was 1.7 miles. The longest distance traveled was 16.2 miles. Fishermen recovered only 15% of the bullhead at points less than 1.0 miles from the point of their release.

Bullhead, like white catfish, did not enter the catch immediately after tagging. The first bullhead tag was returned after 34 days. Only three of the returns were made within 60 days after tagging.

Survival, Mortality, and Harvest

To compensate for nonreporting of tags, bullhead tag returns were adjusted by a mean nonresponse factor of 0.46 calculated for white catfish in a parallel study (Robert R. Rawstron, MS). This correction seems justified, since anglers at Folsom Lake frequently do not distinguish between the species and each is caught using the same techniques.

Brown bullhead, then, had an annual survival rate of 0.52 and a low harvest rate of 0.14. McCammon and Seeley (1961) reported a 0.76 survival at Clear Lake with a harvest of only 0.07 (Table 5).

TABLE 5

Survival and Mortality Rates of Brown Bullhead from Californian Waters

Lake name	s	a	u	v	Source
Folsom Lake	0.52	0.48	0.14	0.34	Present study
Clear Lake	0.76	0.23	0.07	0.16	McCammon and Seeley (1961)

The exploitation rate at Folsom Lake could be increased if night fishing were permitted. At Quabbin Reservoir, Massachusetts, night fishermen, who comprised only 8.5% of the total fishermen, caught 6,856 pounds (61.2%) of the 10,770 pounds of brown bullhead harvested (McCaig, 1963). (During experimental setline fishing by the author at Folsom Lake during the summer of 1964, night sets outfished day sets for bullhead by a ratio of 3.3:1.)

A chi-square test demonstrated that all tags from fish that were 11.0 inches long or longer when tagged returned at a significantly higher rate during the two years than tags from fish less than 11.0 inches long ($\chi^2 = 4.80$; $\chi^2_{0.95,\ 1d.f.} = 3.84$). McCammon and Seeley (1961) showed a similar result for fish 10 inches and longer at Clear Lake in their 1952 study. The differential nonresponse by size measured in this study for white catfish suggests that this phenomenon may be due to variations in nonresponse and not to differential vulnerability of the fish.

Bluegill

General Data

The mean fork length of tagged bluegill was 7.4 inches. They ranged from 6.0–9.5 inches.

Anglers returned 33 reward tags during the two-year study period. Thirty reward tags were returned in the first year. Only three were returned in the second year.

Movement and "Time at Large"

Bluegill moved an average of 1.1 mile from point of tagging to point of capture by the angler. Distances reported ranged from 0–3.4 miles. These determinations were made from 27 tags for which sufficient information was available.

Forty-one percent of the bluegill returns were from the point where they were tagged.

Tagged bluegill were at large from 4–404 days after tagging. Eleven tags were returned within 60 days after tagging.

Survival, Mortality, and Harvest

These parameters suffer for lack of sufficient data, which makes them somewhat less useful. The calculated estimates are as follows:

$s = 0.10$
$a = 0.90$
$u = 0.37$
$v = 0.53$

This low survival rate creates doubt about the accuracy of these estimates. All fish tagged were longer than 6.0 inches and from four to six years old (Tharratt, 1966). Tharratt's sampling during 1962 produced only one fish six years old. Hence, virtually all tagged fish could be expected to die within two years, so the low number of returns after the first year is not surprising. However, the lack of tagging at the beginning of the second year negates any determination of the accuracy of these estimates.

Since so few reward tags were returned, statistical examination of differential return by size was not attempted.

Red-ear Sunfish

General Data

Tagged red-ear sunfish averaged 8.0 inches FL and ranged from 6.0–11.0 inches (Table 2).

Only three nonreward tags were returned, all in the first year.

Rate of Exploitation

Scanty return data allow only a weak estimate of first-year fishing rate. Corrected for the 83% nonresponse calculated for bluegill, this amounted to 0.28, slightly less than for bluegill.

SUMMARY

Largemouth bass over 9.0 inches long (the minimum size tagged) suffered a high annual apparent mortality of 0.89 and an exploitation rate of 0.40. Possible reasons for suspected errors in these mortality estimates are given. They moved an average of only 0.7 mile from point of tagging. Seventy-five % of the reward tags were returned within 60 days after tagging.

Smallmouth bass, for which limited data were available, showed a first-year rate of exploitation of 0.57.

White catfish appeared to be great wanderers, moving an average of 2.3 miles from the point of tagging to point of capture by the angler. Only 8 returns were made within the first 90 days after tagging.

Annual mortality and exploitation rates were 0.45 and 0.19, respectively. These values, and those for other Californian waters, indicate that generally our catfish populations are poorly harvested. The exploitation rate could be increased by opening more areas to night fishing.

Brown bullhead also dispersed around the lake, moving an average of 1.7 mile. Only three of the returns were made within 60 days.

Corrected for mean nonresponse of white catfish, bullhead had an annual mortality rate of 0.48 and an exploitation rate of 0.14. Evidence on the importance of night fishing to bullhead harvest rates is presented.

Bluegill moved an average of 1.1 mile from the point of tagging. Eleven reward tags were returned within 60 days after tagging.

On the basis of limited data, estimates of annual mortality and exploitation rates were 0.90 and 0.37, respectively. Possible errors which make these estimates less reliable are presented.

Red-ear sunfish returns were too few to measure any mortality parameters except an adjusted first-year exploitation rate of 0.28.

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THE DIET OF JUVENILE AND ADULT STRIPED BASS, *ROCCUS SAXATILIS*, IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEM[1]

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More than 4,500 striped bass stomachs were examined during the period 1957–1961. About half contained natural food items. Comparisons were made between size of bass and size of organisms eaten. Major foods were northern anchovies, shiner perch, striped bass, king salmon, carp, crayfish, bay shrimp, mysid shrimp, isopods, scuds, and insect larvae.

INTRODUCTION

Previous reports in varying degree have described foods eaten by striped bass in California (Smith, 1896; Scofield, 1910; Scofield and Bryant, 1926; Scofield, 1928, 1931; Shapovalov, 1936; Hatton, 1940; Johnson and Calhoun, 1952; Skinner, 1962; and Heubach, Toth, and McCready, 1963). The present study was initiated in an attempt to obtain a wider picture.

Incidental collection of striped bass stomachs began in 1957 and continued through 1960. In 1961, monthly samples were obtained throughout the entire area inhabited by striped bass. Work on young-of-the-year bass was completed in 1962 (Heubach et al., 1963). Emphasis after 1962 was placed upon juvenile and adult bass.

Information in this report on the Sacramento-San Joaquin Delta was collected before 1962. The Delta Fish and Wildlife Protection Study of the California Department of Fish and Game has studied the diet of striped bass in the Delta since then and will soon publish the results. Hopefully, understanding of the bass' diet will help explain variations in bass migrations, growth, and year-class strength.

DESCRIPTION OF STUDY AREA

The Sacramento and San Joaquin rivers merge to form a vast network of channels, sloughs, and inland bays terminating in the Pacific Ocean at San Francisco. This inland water system, which comprises the study area, has been described and illustrated in a great number of earlier reports on California's striped bass fishery. For this reason, only a brief description is given in this paper.

Upstream from Carquinez Strait, the water is essentially fresh, depending upon the season. Seaward from the Strait the water becomes more saline and is essentially marine in character (Heubach et al., 1963).

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Juvenile striped bass[3] are found the year around in large numbers above San Francisco Bay, and apparently have no well defined migration pattern (Clark, 1936). Adult bass[4] have well defined migration patterns (Calhoun, 1952; H. K. Chadwick, MS). In the spring, adults disperse throughout the Delta and its tributary rivers to spawn. After spawning, bass return to the lower bays and adjacent coastal areas for the summer. In recent years, many have remained in the lower bays during fall and winter, while others have returned to the Delta.

METHODS

The striped bass habitat was divided into six separate food communities: (i) San Francisco Bay, (ii) San Pablo Bay, (iii) Sacramento River and bays from Crockett to Pittsburg, (iv) Delta, (v) lower Sacramento River, and (vi) upper Sacramento River.

Bass were obtained by angling, trawling, and gill netting in each area. They were separated into three size groups (6 to 10 inches—age I; 11 to 15 inches—age II; and 16 inches and larger—age III and older). The sampling goal was a minimum of 20 bass containing food in each size group present in each area every month.

In the field, stomach contents were individually wrapped in cheesecloth and preserved in 10% formalin. In the laboratory, these contents were identified (Table 1) and the volume of each item was measured in a graduated glass cylinder by water displacement.

[3] Bass less than 16 inches total length (the minimum legal size in California).
[4] Bass 16 or more inches total length.

TABLE 1

Common and Scientific Names of Organisms Cited in This Report

Vertebrates

American shad	*Alosa sapidissima*
Carp	*Cyprinus carpio*
Gobies	*Gobiidae*
Goldfish	*Carassius auratus*
Green sunfish	*Lepomis cyanellus*
Jacksmelt	*Atherinopsis californiensis*
King salmon	*Oncorhynchus tshawytscha*
Northern anchovy	*Engraulis mordax*
Northern midshipman	*Porichthys notatus*
Pacific herring	*Clupea pallasii*
Pile perch	*Rhacochilus vacca*
Pond smelt	*Hypomesus transpacificus*
River lamprey	*Lampetra ayresii*
Sacramento smelt	*Spirinchus thaleichthys*
Shiner perch	*Cymatogaster aggregata*
Splittail	*Pogonichthys macrolepidotus*
Staghorn sculpin	*Leptocottus armatus*
Starry flounder	*Platichthys stellatus*
Surf smelt	*Hypomesus pretiosus*
Threadfin shad	*Dorosoma petenense*
Tomcod	*Microgadus proximus*
White croaker	*Genyonemus lineatus*
White seaperch	*Phanerodon furcatus*

Invertebrates

Bay shrimps	*Crago* spp. and *Palaemon macrodactylus*
Black flies	Simuliidae
Caddisflies	Hydropsychidae
Cladocerans	Cladocera
Clam	*Macoma nasuta*
Copepods	Copepoda
Crayfish	*Pacifastacus leniusculus*
Ghost shrimp	*Callianassa californiensis*
Isopod	*Synidotea* sp.
Mayflies	Ephemeroptera
Market crab	*Cancer magister*
Midges	Tendipedidae
Moth flies	Psychodidae
Mysid shrimp	*Neomysis awatschensis*
Periwinkle	*Littorina* sp.
Scuds	*Corophium* spp.
True flies	Diptera

RESULTS

The results for each assigned locality were summarized on a seasonal basis by percentage frequency of occurrence (Tables 2-5) and percentage volume (Figures 1-4).

About half (2,259) of the 4,551 juvenile and adult striped bass stomachs examined contained natural food. Although the sample size seems large, some areas were not adequately sampled and in many cases samples within size groups were small.

TABLE 2

Food Items Eaten by Striped Bass During Spring, by Area,* in Percentage Frequency of Occurrence †

Food items	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Verterbrates						
Anchovy	29	15	10	‡	‡	‡
Shiner perch	10	--	--	‡	‡	‡
Herring	--	--	20	‡	‡	‡
Staghorn sculpin	6		--	‡	‡	‡
Surf smelt			2	--	‡	‡
Sacramento smelt		--	3	--	‡	‡
King salmon			3		22	62
Lamprey		--	--		9	--
Striped bass	--			2		--
Pond smelt	‡	‡	--	--	7	--
Carp	‡	‡	--		16	--
Unknown fishes	28	13	10	4	31	18
Invertebrates						
Bay shrimps	8	69	19	--	‡	‡
Crayfish	‡	‡	‡	--	7	--
Isopod	--	16	30	--	‡	‡
Mysid shrimp	‡	6	17	66	7	‡
Scuds	‡	‡	6	11	--	--
Copepod	‡	‡	--	7	--	--
Cladocerans	‡	‡	--	7	--	--
Mayflies	‡	‡	‡	--	--	18
Midges	‡	‡	‡	--	--	13
Unknown Dipterans	‡	‡	‡	--	--	7
Sample size	65	68	127	134	56	45

* Areas: 1—San Francisco Bay; 2—San Pablo Bay; 3—Crockett to Pittsburg; 4—Delta; 5—Lower Sacramento River; 6—Upper Sacramento River.
† Organisms with a frequency of occurrence of 2 or less are omitted.
‡ This forage organism is not normally present.

Spring Diet (March 1–May 31)

San Francisco Bay

Stomachs of 65 adult bass taken by angling contained food. Shiner perch and northern anchovies were the two most important items. Shiner perch constituted 50% and anchovies 34% by volume. Staghorn sculpins and bay shrimps were minor items in the diet.

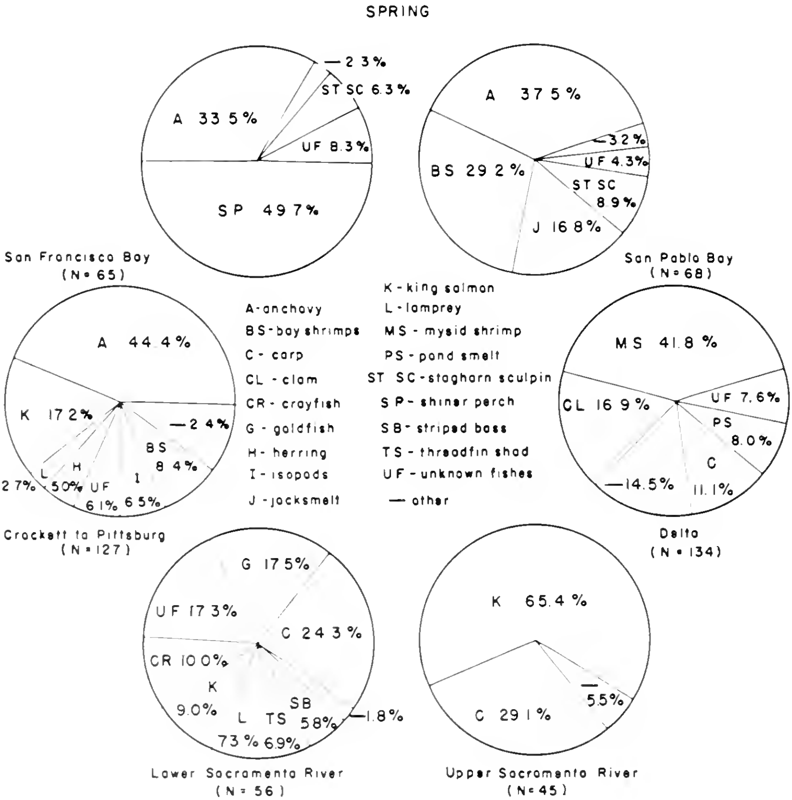

FIGURE 1—Food items found in striped bass stomachs during spring, in percentage of total volume and by area.

San Pablo Bay

Northern anchovies and bay shrimps constituted 67% by volume of the food eaten by 68 bass in all three size groups. Isopods occurred frequently; however, because of their small size they were not important volumetrically.

Crockett to Pittsburg

In 127 stomachs containing food from all three size groups, northern anchovies were the major item by volume and king salmon were second. Mysid shrimp, isopods, Pacific herring, and bay shrimps occurred frequently, but added little volume.

Delta

Mysid shrimp occurred in 66% of 134 bass stomachs from all three size groups containing food. Mysids constituted 42% of the total volume. Copepods, cladocerans, and scuds were minor diet items. The stomachs of most adults were empty both here and in the next two areas.

Lower Sacramento River

Carp constituted the most important food in the stomachs of 56 bass of all three size groups from the lower Sacramento River. Several other fishes and crayfish were important by volume. Fingerling king salmon occurred in 22% of the stomachs and formed the principal diet of bass in the Courtland area.

Upper Sacramento River

In the upper Sacramento and lower American rivers, king salmon were the major diet item of 45 juvenile bass. Salmon comprised 65% of the stomach contents by volume and were found in 62% of the bass sampled. Aquatic insect larvae, particularly caddisflies and true flies, were the only other important foods.

TABLE 3

Food Items Eaten by Striped Bass During Summer, by Area,* in Percentage Frequency of Occurrence †

Food items	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Vertebrates						
Anchovy	46	31	34	‡	‡	‡
Shiner perch	28	--	-	‡	‡	‡
Herring	8	4		‡	‡	‡
Tomcod	6		-	‡	‡	‡
Staghorn sculpin	3	--	--	‡	‡	‡
Starry flounder	3	-	--	‡	‡	‡
Jacksmelt	--	--	2	‡	‡	‡
Gobies	2		--	-	‡	‡
King salmon	--	--	2	--	30	7
Lamprey	--	-	--	--	-	4
Striped bass	-	-	28	23	4	--
Pond smelt	‡	‡	-	--	8	--
Carp	‡	‡	-	--		9
Unknown fishes	23	5	--	7	34	9
Invertebrates						
Ghost shrimp	3	--	--	‡	‡	‡
Market crab	3	7	--	‡	‡	‡
Bay shrimps	10	45	25	--	‡	‡
Crayfish	‡	‡	‡	--	12	5
Isopod	5	26	23	--	‡	‡
Mysid shrimp	‡	‡	13	91	--	‡
Periwinkle	--	5	--	--	--	--
Seuds	‡	‡	--	8	19	23
Mayflies	‡	‡	‡	--	--	3
Caddisflies	‡	‡	‡	--	--	21
Midges	‡	‡	‡	--	10	10
Black flies	‡	‡	‡	--	--	2
Moth flies	‡	‡	‡	--	--	11
Unknown Dipterans	‡	‡	‡	--	--	2
Sample size	196	74	127	173	104	184

* Areas: 1—San Francisco Bay; 2—San Pablo Bay; 3—Crockett to Pittsburg; 4—Delta; 5—Lower Sacramento River; 6—Upper Sacramento River.
† Organisms with a frequency of occurrence of 2 or less are omitted.
‡ This forage organism is not normally present.

Summer Diet (June 1–August 31)

San Francisco Bay

Northern anchovies and shiner perch were the principal dietary items found in 196 adult bass stomachs containing food. Anchovies were most important both in numbers and volume. Pacific herring and Pacific tomcod were less important but comprised 13% by volume. Bay shrimps appeared in 10% of the bass stomachs containing food.

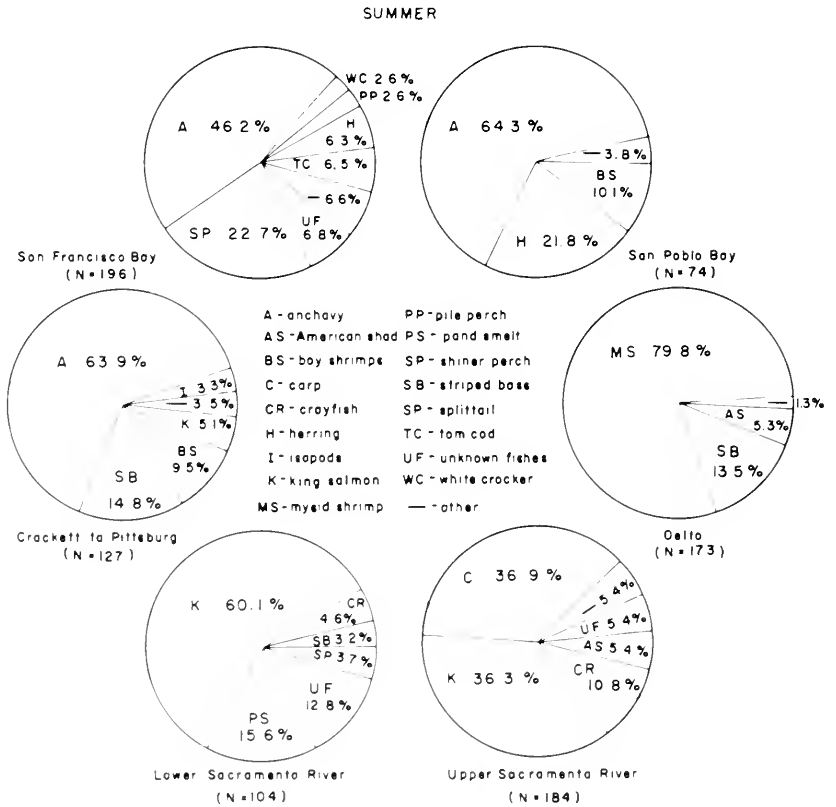

FIGURE 2 Food items found in striped bass stomachs during summer, in percentage of total volume and by area.

San Pablo Bay

Analysis of 74 bass stomachs of all three size groups showed that northern anchovies made up 64% of the diet by volume. Bay shrimps and isopods were the only other items that appeared frequently.

Crockett to Pittsburg

Northern anchovies were the major dietary item both in frequency and volume in 127 bass of all three size groups containing food. Striped bass and bay shrimps were less important, comprising one-fourth the total volume. Isopods and mysid shrimp were frequently present but did not add greatly to the total volume.

Delta

Mysid shrimp were the preferred food of 173 bass of all three size groups examined (169 bass were juveniles). Mysids were found in 91% of the sample and represented 80% of the total volume. The only other food item of significance consisted of small striped bass, which occurred in 23% of the stomachs and comprised 14% of the total volume.

Lower Sacramento River

King salmon occurred most often in the diet and comprised 60% by volume of all food consumed by 104 bass. Pond smelt and crayfish appeared in minor numbers and volume. The frequency of occurrence of scuds was second only to that of salmon; however, due to the scuds' small size they added very little to the total volume eaten.

Upper Sacramento River

King salmon and carp comprised 73% by volume of food eaten by 184 juvenile bass. Crayfish appeared in minor quantities and contributed 11% to the total volume. Scuds and the larvae of caddisflies and true flies occurred frequently in stomachs but contributed little to the volume.

Fall Diet (September 1–November 30)

San Francisco Bay

Northern anchovies and shiner perch occurred in almost equal volumes and together made up over half the volume of all food eaten by

TABLE 4

Food Items Eaten by Striped Bass During Fall, by Area,* in Percentage Frequency of Occurrence †

Food items	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Vertebrates						
Anchovy	30	15	8	‡	‡	‡
Shiner perch	26	--	--	‡	‡	‡
Herring	4	--	--	‡	‡	‡
Tomcod	8	--	--	‡	‡	‡
Staghorn sculpin		3	--	‡	‡	‡
Starry flounder	4	--	--	‡	‡	‡
Surf smelt	--	--	3	‡	‡	‡
King salmon	--	--	--	--	--	2
Lamprey		4	--	--	‡	--
Striped bass		3	16	7	--	--
Green sunfish	‡	‡	--	--	--	5
Carp	‡	‡	--	--	--	41
Unknown fishes	28	14	12	3	10	17
Invertebrates						
Ghost shrimp	--	9	--	‡	‡	‡
Market crab	3	2	--	‡	‡	‡
Bay shrimps	30	55	34	2	‡	‡
Crayfish	‡	‡	‡	--	30	--
Isopod	19	25	23	--	‡	‡
Mysid shrimp	‡	‡	25	88	--	‡
Periwinkle	--	5	--	--	--	--
Scuds	‡	‡	--	--	63	24
Mayflies	‡	‡	‡	--	--	10
Caddisflies	‡	‡	‡	--	--	14
Midges	‡	‡	‡	--	40	--
Unknown Dipteraus	‡	‡	‡	--	--	3
Sample size	106	183	119	138	31	103

* Areas: 1—San Francisco Bay; 2—San Pablo Bay; 3—Crockett to Pittsburg; 4—Delta; 5—Lower Sacramento River; 6—Upper Sacramento River.
† Organisms with a frequency of occurrence of 2 or less are omitted.
‡ This forage organism is not normally present

106 adult bass. Pacific herring and Pacific tomcod comprised 22% by volume but did not occur frequently. Bay shrimps and isopods occurred often in stomachs but contributed little to the total volume.

San Pablo Bay

Bay shrimps made up 25% of the diet by volume, and appeared in over half of 183 stomachs containing food. Northern anchovies occurred more often than staghorn sculpins, but the sculpins, being larger, were more important in volume. Together, these two fishes constituted 38% of the volume. Isopods constituted the second most frequent item, although they were of little importance by volume.

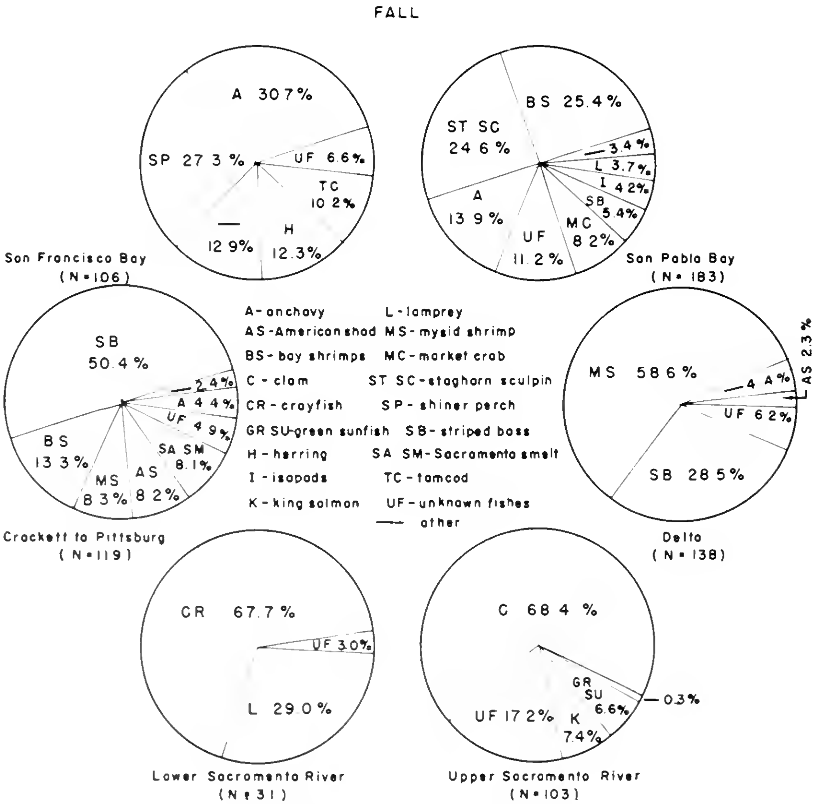

FIGURE 3—Food items found in striped bass stomachs during fall, in percentage of total volume and by area.

Crockett to Pittsburg

In 119 stomachs containing food, young striped bass constituted 50% of the diet by volume. Bay shrimps, mysid shrimp, and isopods occurred frequently, and the first two made up 22% of the diet by volume.

Delta

Mysid shrimp comprised the major portion of the diet by both number and volume. Young striped bass also appeared in significant volume. In the sample of 138 fish containing food, all but 6 were under 16 inches long.

Lower Sacramento River

Thirty-one of 109 fish contained food. The majority had scuds, midges, or both in their stomachs, but crayfish and river lampreys made up 97% of the total volume.

Upper Sacramento River

Carp accounted for 68% of the diet by volume and 41% by frequency of occurrence in 103 bass. Scuds and insect larvae occurred frequently but added an insignificant amount by volume because of their small size.

Winter Diet (December 1–February 28)

San Francisco Bay

In 16 adult bass containing food, white seaperch and Pacific herring comprised 64% of the diet by volume. Bay shrimps appeared most often but contributed little to the volume.

TABLE 5

Food Items Eaten by Striped Bass During Winter, by Area,* in Percentage Frequency of Occurrence †

Food items	Area 1	Area 2	Area 3	Area 4
Vertebrates				
Anchovy	--	4	--	‡
Herring	13		--	‡
Sacramento smelt	--		14	‡
Lamprey	--	‡3	--	1
Striped bass		--	14	8
Pond smelt	--	--	12	--
Threadfin shad	‡	‡		8
Unknown fishes	56	8	21	15
Invertebrates				
Bay shrimps	19	70	39	--
Isopod	--	48	18	--
Mysid shrimp	‡	3	29	74
Periwinkle	--	3	--	--
Sample size	16	118	28	61

* Areas: 1—San Francisco Bay; 2—San Pablo Bay; 3—Crockett to Pittsburg; 4—Delta.
† Organisms with a frequency of occurrence of 2 or less are omitted.
‡ This forage organism is not normally present.

San Pablo Bay

Bay shrimps accounted for 47% of the diet by volume and occurred in 70% of the stomachs containing food. Isopods occurred in 48% of the bass containing food but accounted for less than 8% of the total volume. All but 15 of 118 fish containing food were less than 16 inches long.

Crockett to Pittsburg

Twenty-eight bass containing food were collected. Small striped bass constituted 34% of the diet by volume. Sacramento smelt and pond smelt accounted for 31%. Smaller organisms, such as bay and mysid shrimps and isopods, occurred frequently but added less than 13% by volume.

Delta

Mysids appeared in 74% of 61 bass containing food. Striped bass and threadfin shad comprised 51% of the stomach contents by volume.

Sacramento River

Six stomachs containing food from the lower Sacramento River near Rio Vista indicate that river lampreys, small striped bass, pond smelt and bay shrimps appear in the diet. However, the sample is too small to show the amounts reliably.

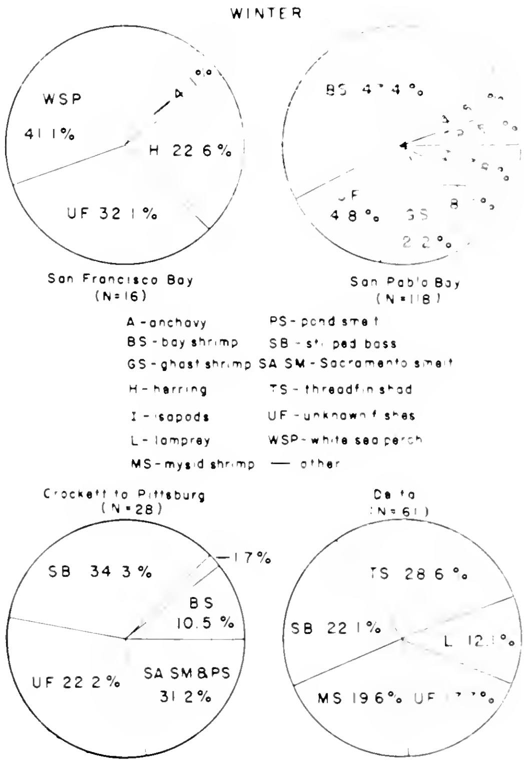

FIGURE 4—Food items found in striped bass stomachs during winter, in percentage of total volume and by area.

Food Selection

Although bass ate many different organisms occasionally, there were instances in which a minor item occurred in large numbers in one or two specimens and formed the only record of that item in the diet.

TABLE 6

A Comparison of Four Major Food Items Found in Small, Medium, and Large Bass by Mean Percentage Frequency of Occurrence. All Samples Were from the Area Between Crockett and Pittsburg.

Date	Fish 6 to 10 inches					Fish 11 to 15 inches					Fish over 16 inches				
	No. bass examined w food	*Neomysis*	Isopods	Shrimps	Fishes	No. bass examined w food	*Neomysis*	Isopods	Shrimps	Fishes	No. bass examined w food	*Neomysis*	Isopods	Shrimps	Fishes
5/2/62	16	38	63	13	25	18	17	44	17	95	3		33	33	100
5/31/62	8	50	25	13	25	3		100	33	67	3			67	67
6/28/62	8	*	13	38	83	4	*	25		100	1	*			100
7/27/62	2	*			100	12	*	8	17	92	1	*		—	100
8/24/62	21	18	33	13	57	9		33	33	67	1			—	100
8/19/63	4	25	25		100	11	9		9	92	2			50	100
11/29/62	12	50	17	25		8	13		75	38	5		20	40	100
Totals	**71**	**211**	**176**	**132**	**390**	**65**	**39**	**210**	**184**	**551**	**16**	**0**	**53**	**190**	**667**
Mean percentage frequency of occurrence		**42**	**25**	**19**	**55**		**8**	**30**	**26**	**79**		**0**	**8**	**27**	**95**

* *Neomysis* excluded from the sample these days, since it did not occur in any size groups listed

For example, 2 of 443 stomachs from San Pablo Bay contained northern midshipmen, a species found in the Bay all year. One stomach contained 9 midshipmen, and the other 19. No other food was present in these 2 bass. Apparently, these items were selected deliberately; other bass caught at the same time in the same area contained different food items.

In the area between Crockett and Pittsburg, all three size groups of bass were collected at the same time, and significant differences were noted in the size and kind of food selected (Table 6). Smaller bass selected small food items such as mysid shrimp, while large bass generally ate larger items, such as fish. Isopods and shrimps were abundant medium-sized food items in the area and occurred frequently in stomachs of 11- to 15-inch bass. Shapovalov (1936) also noted size selectivity of bass in Waddell Creek lagoon. There, the diet of large bass consisted primarily of fishes, while smaller bass fed almost exclusively on small crustaceans.

DISCUSSION

Striped bass eat a wide variety of the foods available within their habitat. Important foods include both pelagic forms such as anchovies and bottom dwellers such as shrimps, but animals which live in the bottom, such as annelid worms and clams, seldom contribute significantly to their diet.

Factors other than overall abundance obviously affect an organism's availability to bass. For example, pond smelt, American shad, white catfish, and various native minnows are much more abundant in the Delta and Sacramento River than their occurrence in the diet indicates. Conversely, carp and king salmon are probably less abundant than their occurrence in the diet indicates. While identification of the factors controlling availability would be important in understanding ecological relationships, the necessary facts are not available.

The migrations of the bass are the primary factor causing seasonal variations in their food habits. However, diets in each area also varied significantly, reflecting migrations of forage organisms and seasonal fluctuations in abundance of endemic forms. Major seasonal variations were associated with the following:

1) The upstream migration by anchovies, which become most numerous in Carquinez Strait from June through August (Messersmith, 1966).

2) The distribution of young-of-the-year striped bass, which is related to the amount of runoff (Chadwick, 1964).

3) The downstream migration of young king salmon, which occurs primarily in the spring and early summer.

At times striped bass fed heavily on their own young and on young king salmon. The effects of this predation on these populations can not be determined from the available data.

Since most of this study's collections from the Delta were made before 1962, and threadfin shad did not become abundant until after this, these collections do not reflect the present situation. Threadfin shad now make a substantial contribution to the bass' diet there (Don E. Stevens, unpublished data).

Throughout their range in the Sacramento-San Joaquin system young-of-the-year striped bass rarely eat fish (Heubach et al., 1963). The results of this study indicate that juveniles frequently eat fish, but the size at which they turn to a fish diet apparently varies with locality. In the Delta, juveniles ate invertebrates almost exclusively, while in other areas fish generally dominated their diet on a volume basis even though various invertebrates were eaten frequently. Since many of the fish eaten in other areas are abundant in the Delta and mysid shrimp, the primary invertebrate eaten in the Delta, are abundant immediately downstream from there, the most likely hypothesis for explaining the difference is that the greater turbidity in the Delta severely limits predation on fishes.

The results of this study are similar to an analysis of stomach samples obtained in 1947 and 1948 (Johnson and Calhoun, 1952). Both indicate that shrimp and anchovy are major food items during summer and fall in the San Pablo Bay area, but shrimp are apparently less important now. Both showed mysid shrimp were a major food of small bass in the Delta during winter and spring.

SUMMARY

The year-round diet of striped bass in the Sacramento-San Joaquin River system was described from 4,551 juvenile and adult bass, 2,259 of which contained food. Collections were combined by season and area to show variations in the bass' diet. Major food items in the diet of bass were found to be northern anchovies, shiner perch, striped bass, king salmon, carp, crayfish, bay shrimps, mysid shrimp, isopods, scuds, and insect larvae.

Limited data on selection of food by different ages of bass indicated that there is a positive correlation between size of fish and size of organisms eaten.

Diet varied seasonally in response to the migrations of food organisms, and fluctuations in the abundance of endemic foods. Bass ate a wide variety of pelagic and bottom animals, but animals living in the bottom seldom contributed significantly to their diet. Factors other than abundance obviously affected an organism's availability, but not enough is known to identify these factors.

Juvenile bass (less than 16 inches TL) seldom ate fish in the Delta, and it is hypothesized that this is due to the high turbidity there.

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NOTE

NORTHERLY OCCURRENCES OF KELP BASS, *PARALABRAX CLATHRATUS* (GIRARD), SINCE 1959

Kelp bass, inhabiting inshore kelp beds and island shores from Magdalena Bay, Baja California, to Monterey Bay, California, rank among the five most important sport fishes in southern California. Tagging studies (Young, 1963) indicate that the species is nonmigratory, and few individuals had been encountered north of Point Conception before 1959.

Recent captures of kelp bass at Half Moon Bay, Fort Ross, and Trinidad, California, suggest that northerly occurrences of this species may be correlated with periods of warm ocean temperatures. Following the warmwater period 1957 through 1959, small individuals began to appear in sport fish catches at Monterey Bay (Miller and Gotshall, 1965). At least 282 sport-caught kelp bass were sampled in the Monterey Bay area between 1959 and 1965, with the best catches being reported in 1963 (D. J. Miller, pers. corres.). Underwater observations within the Bay during December 1963 revealed large numbers of kelp bass as small as 8 inches. Sport-caught fish, however, ranged from 11 to 20 inches (29.5–51.5 cm), total length.

On the basis of the following occurrences, the recorded range of the kelp bass is extended more than 280 miles northward to Trinidad Head, Humboldt County, California (lat. 41° 03′ N, long. 124° 09′ W).

1. A skiff fisherman captured a 15-inch (37.8 cm TL) specimen in November 1959 at Half Moon Bay, California (lat. 37° 29′ N, long. 122° 28′ W).

2. On September 21, 1963, a 14-inch (36.3 cm TL) spent female was speared in water 10 feet deep by Paul Lilljengren, near Fort Ross, California (lat. 38° 31′ N, long. 123° 15′ W).

3. Two specimens have been captured from Trinidad Pier (lat. 41° 03′ N, long. 124° 09′ W). The first, an immature female measuring 12.5 inches (31.5 cm TL), was caught February 21, 1965, by Archie Hamilton in approximately 20 feet of water. The second, a 16-inch (40.3 cm TL) maturing female, was taken by Joe Lindgren in 10 to 15 feet of water on August 6, 1965.

Our examination of otoliths and scales from the northern specimens suggests no apparent deviation from the growth rate for southern California kelp bass (Young, 1963). Although the presence of immature, maturing, and spent gonads suggests the northern migrants may reproduce, we have not observed gravid females or juvenile specimens.

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—*J. Gary Smith and Daniel W. Gotshall, Marine Resources Operations, California Department of Fish and Game, April 1966.*

BOOK REVIEWS

Inland Fisheries Management

Edited by Alex Calhoun; California Dept. Fish and Game, Sacramento, 1966; 546 p., illustrated. $4 (paper). Sold only by Office of Procurement, Documents Section, P. O. Box 1612, Sacramento, California 95807.

As stated in the preface, "Fishery biologists will now soon have a handbook like those the physical scientists take for granted. However, this volume represents another step in that direction. It is aimed primarily at the field men responsible for California's inland fisheries: the biologists, the men who operate the fish hatcheries, and the wardens. Its purpose is to give them ready access to a large body of inland fisheries fact and theory." The authors have supplemented material from the published literature with liberal amounts of information based on recent management experience.

The manual consists of 76 chapters authored or coauthored by 30 contributors. The titles of a few chapters, "Population Dynamics and Population Estimation", "Fish Marking", "Electrofishing", "Yields of California Lakes", "Maximum Swimming Speed of Fishes", "Fishways", "Lake Destratification", and "Fisheries Oriented Computer Programs" indicate the wide range of subject matter covered. There are also individual chapters on inland fish species found in California. A list of references accompanies each chapter and a thorough index concludes the volume.

All in all, this reference work will help to fill a long-felt need.—*Leo Shapovalov.*

The Crabs of Sagami Bay

By Ture Sakai; Maruzen Co., Ltd., Tokyo, 1965; xvi + 206 p. in English + 92 p. in Japanese + 32 p., 100 colored plates, 1 map. $25. Send all orders originating in Asia to Maruzen Co.; send all orders originating elsewhere to East-West Center Press, Honolulu.

The Emperor of Japan for many years has been interested in marine biology and his valuable collections include many marine invertebrates from Sagami Bay. This beautiful book is a catalogue of the Sagami Bay crabs collected by His Majesty.

In my judgment, the attractive and accurate plates of water colors painted from live specimens by Mrs. Sakai form the outstanding feature of the book.

The text in English and Japanese covers synonymy and distribution of 344 species, including the synonymy and homonymy of some of the broadly distributed Indo-Pacific species. Verbal descriptions are presented only for some of the less common genera and species. Three new species and two subspecies are reported for the first time.

Four of the crabs discussed and illustrated also occur off California: *Cancer gibbosulus*, *C. amphioetus*, *C. oregonensis* (in Japan = *C. anaglyptus*), and *Pachygrapsus crassipes*.

It is unfortunate that more of the faunal works originating from the United States have not contained similar detailed, quality color illustrations of the species under discussion.

This book is a true collector's item. Its chief attraction, aside from its unique royal connection, lies in its lovely, glossy color plates which may be appreciated either for their life-like accuracy or for their sheer, breathtaking, artistic and aesthetic value—*Daniel W. Gotshall.*

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